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ENGINEERING.—*From material to structure.*[1]

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"The name of the song is called 'Haddock's Eyes'."

"Oh, that's the name of the song, is it?", Alice said, trying to feel interested.

"No, you don't understand," the Knight said, looking a little vexed, "that's what the name is *called*. The name really is 'The Aged, Aged Man'."

"Then I ought to have said 'That's what the *song* is called'?" Alice corrected herself.

"No, you oughtn't: that's quite another thing. The *song* is called 'Ways and Means:' but that's only what it is called, you know!"

"Well, what *is* the song, then?" said Alice, who was by this time completely bewildered.

"I was coming to that," the Knight said, "The song really *is* 'A-sitting on a gate'."

The title of my talk is called "From Material to Structure." I hope the talk itself is somewhat more closely related to what the title is called than it was in the case of the Knight's song. However, words are stubborn and do not easily adapt themselves to accurate expression of our thoughts. Only under the hand of a poetic genius do they become plastic and shape to the thought of the writer. When we who are not poets are allowed to be loquacious and can hedge each word about by a multitude of qualifying adjectives and phrases we may force them to give a reasonable picture of what we wish to say.

In a title it is possible to be loquacious. You have all seen many loquacious titles, but they are not attractive. The title "From Material to Structure" was chosen for its brevity and does not give an accurate picture of the subject of this paper. It is, in fact, so general that volumes could be written, and have been written, on many topics included in its scope.

[1] Received February 15, 1933. Address of the retiring president, delivered before the Philosophical Society of Washington, January 14, 1933.

For that reason I shall spend some time supplying in my introduction some of the many qualifying adjectives and phrases which were not included in the title. As a basis for this I referred to a dictionary. Here, as usual, there was a wealth of definitions of different and only remotely related uses of the words "material" and "structure." Among these I sought out the ones which might fit into the title:

> "Material—The substance or substances or the parts, goods, stock, or the like, of which anything is composed or may be made."
>
> "Structure—Something constructed or built."

These seemed to fit the case but still were not quite definite enough to start on. Looking further I found:

> "Construct—To put together the constituent parts of (something) in their proper place and order."

To stay within some bounds let us first limit "structures" to "mechanical" structures—structures (to paraphrase a definition) "which by their design may serve to transmit or modify force or motion so as to produce some given effect or do some desired kind of work." This is somewhat more comprehensive than the usual engineering use of the word structure and we have ample material to discuss. Monkey wrenches and mill stones, automobile engines and airships, bells and bridges, all serve to transmit or modify force or motion so as to produce some given effect or do some desired kind of work. It is from this purely mechanical aspect that we shall consider them.

"From Material to Structure" would with this limitation include all the intricate steps involved in putting together ". . . in their proper place and order," "the substance or substances . . . of which anything may be made" to form a finished mechanical structure. We can, of course, consider only an infinitesimal aspect of these, but a short time devoted to a few generalities may serve to show the relation of this aspect to their bewildering complexity.

To put the materials of a mechanical structure in their proper place and order demands a knowledge of arrangements of materials capable of producing the desired effect or doing the desired kind of work. The structure must be designed before it can be constructed. This means not simply arranging some material in a suitable way but arranging suitable materials in suitable ways. There may be widely different ways of serving the same purpose.

A bridge serves the purpose of transmitting the loads of the traffic over it to its foundations and abutments. The proper place and order for the materials of a bridge of stone which shall serve this purpose

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satisfactorily are not the proper place and order for the materials of a bridge of steel. The design involves, then, the relationships between properties of the material, the geometrical configuration of the structure and the purpose it is to serve.

It involves also the methods of shaping the individual pieces so that they will fit in their proper places. A certain material shaped in a certain way may be admirably adapted to a purpose, but the design is useless if no methods are available to give the material the desired shape, and another shape or even another material in another shape must be used. Long before the advent of the steel automobile body, it was known that properly shaped steel would serve the purpose better than wood. All that was lacking was the means to give it the proper shape. With the development of autogeneous welding processes and of the art of sheet metal stamping, the modern "one piece" automobile body came into being. All of you know what a change it has made in the appearance of the automobile. With the advent of new methods of shaping materials, structures designed to serve the same purpose may change wholly out of semblance to their original shape.

Into the design enters also the problem of economical construction. Costly materials will be discarded in favor of cheaper materials, costly methods of fabrication in favor of cheaper methods of fabrication, and the shape of the finished structure may be altered radically under the influence of these considerations, and not only cheaper but in most cases much more serviceable structures will result.

Although we are limiting our discussion to mechanical structures, the purposes they serve are not always purely mechanical. A house, for example, is a mechanical structure in that it serves the purpose of keeping the rain and snow from our heads, of excluding undesired currents of air, of furnishing a smooth and solid support for our feet. Its proper design and construction is, therefore, a mechanical problem.

A house which merely served the mechanical purposes of a house would hardly be considered satisfactory. We wish windows to let in the light. These must be both mechanically and optically satisfactory. We use the walls to keep out heat in summer and keep it in in winter. The walls should be not only adequate mechanically but afford adequate thermal resistance. Wood and stone and brick are poor conductors of heat, and walls of these materials which are mechanically adequate serve fairly well as heat insulators. Metal is a relatively good conductor of heat. Metal walls of the house of the future will divide

their mechanical and thermal functions between two materials, and their design will involve the satisfactory integration of structural metal with heat insulating materials of little or no mechanical value.

With all the conceivable physical purposes of a house adequately served, we still do not have a house. Intangible emotional factors, which may be loosely designated by the captions—art and style—frequently outweigh other considerations. A house does not serve its purpose unless in some measure it satisfies emotional needs. Although, in varying degree, these intangible factors influence practically every step from material to structure, to discuss them further would lead too far afield.

Thinking from material to structure we think first of available materials and their properties, then fabricated parts, then assemblages of fabricated parts, and finally of a finished structure or machine in service. Each material or group of materials furnishes the basis for a great variety of structures whose structural and dynamic possibilities are conditioned in large measure by the properties of the materials out of which they are made. From one aspect the problem of design is the problem of developing the structural properties of the materials. The line of thought from material to structure is, however, in itself, sterile. Design is intricately bound up with construction, and construction with design, but dominating them both is the purpose "to produce some given effect or do some desired kind of work."

To make our thought fruitful we must think also from the standpoint of the user of the structure. A structure is designed to serve a certain purpose. It serves that purpose in a more or less satisfactory way. From this standpoint the problem of design is to improve the quality of that service, either by improvement of the existing structure or by the substitution of a new and improved one. The designer analyzes the way in which the structure is satisfactory and the particulars in which it is unsatisfactory and reasons back through assemblages and fabricated parts, questioning their design, to the materials of which they are constructed, questioning their suitability for the purpose. He may even go further, inquiring into the possibility of securing or producing new materials with more desirable properties. Here, however, we leave the field of mechanics and enter into the field of metallurgy and chemistry.

The distinction I have just made between the two lines of thought —from material to structure and from structure to material—is, of course, largely artificial. No such sharp and clear distinction exists. Nevertheless, the distinction is real. They are two definitely different

habits of thought of two different types of engineers engaged in construction in its broadest sense. Although, in actual work, both will continually think forwards from material to structure in service and backwards from structure in service to material, the materials engineer and the designer who works with him will the more generally picture to themselves the structural possibilities of the materials at hand, and the operating engineer and the designer who works with him will the more generally picture to themselves the needs of the service and from them the designs and materials needed for a structure to serve that particular purpose.

Of these two orders of thought, the one from structure to material, is the more direct response to human desires and consequently much the older. That of the materials engineer, from material to structure, is a later development and more artificial.

"Suitable materials" arranged in "suitable ways": that is our desire. How shall we know that it is realized? The most direct answer is to build the structure and try it out, and, in fact, that it is the final answer. This is a service test in the strict sense of the words. If a service test were the only answer, structural progress would be slow and costly. A San Francisquito dam, a Quebec bridge, a poorly welded caisson in New York, a Knickerbocker Theater, a broken automobile axle: these all represent service tests that prove by the resultant loss of life and property that in these structures there were not suitable materials suitably arranged.

> "And answered Nature, merciful and stern;
> 'I teach by killing, let the others learn'."[3]

Much is gained if we can know beforehand that certain materials arranged in certain ways either will or will not make satisfactory structures. For this purpose we have materials and structural testing: materials testing to search out and measure the structurally significant properties of the material, to determine how they persist or are modified by the processes of fabrication and construction, and finally to prescribe the tests to which materials entering into given structures shall be subjected; and structural testing to determine the relations of the strength and other structurally significant properties of given geometrical configurations of materials to the properties of the material itself.

The final qualifying adjectives and phrases may now be added to make the title read:

[3] CHARLOTTE PERKINS STETSON. *In this our world.*

"Mechanical Testing of Materials and Structures in the Passage from Material to Structure."

Historically, service tests preceded materials tests or even structural tests by many years. Our pre-paleolithic ancestor found that a stick of wood in the hand formed a useful implement in securing his food or in settling various disputes with other men. At first it was probably any likely looking stick of wood picked up on the spur of the moment, but soon he learned that all sticks of wood were not equally serviceable, and a stick which had successfully withstood a service test on the skull of an enemy was preserved for the next encounter. At some time in his progress toward civilization he learned that it was not necessary to await an actual encounter to try out a stick, and structural tests were made on the nearest stump or rock.

With the shaping of the stick into a club came a new problem, the determination in advance of the laborious process of manufacture, that the materials chosen for fabrication would produce a club which would satisfactorily stand the service test. In some such way materials testing began.

As the gap between raw material and finished product grew greater, the importance of materials tests increased because of the greatly increased labor which would be wasted by fabricating unsuitable materials and the greatly increased danger from unsatisfactory structures. At first the materials tests differed but slightly in character from the service tests on the finished product, but in course of time many of them changed their character so completely that their connection with the ultimate service tests was remote and obscure.

In this development, materials and structural testing remained, through many centuries, an art intimately associated with, and a part of, the art of manufacture. Each particular manufacturing trade developed a technic of materials and structural tests necessary to its success.

This technic was largely a "rule of thumb" technic, based upon qualitative differences in behavior, often impossible to express in words, and its correct appreciation and interpretation demanded an intimate familiarity with the material, gained through years of experience in fabricating and using it. It is hard for us today, with our more scientific way of thinking, to realize the extent to which these "rule of thumb" tests were developed. Although they were often mixed with what seems to us gross superstition, such as ascribing unexplained failures to the action of malevolent demons, nevertheless they were sufficient to guide highly technical processes to successful

results. We need only recall the skill of the master armorer who rejected a piece of steel for no better reason than that "it did not feel right under the hammer." By the use of criteria, many seemingly as vague as this, were produced the blades of Toledo and Damascus.

The great industrial progress of the nineteenth and twentieth centuries with its increased specialization and multiplication of steps of partial fabrication, has been gradually destroying the intimate personal contact of the worker with the materials which he fabricates. Raw material on its way to the finished structure may now pass through dozens of hands, each contributing its share in shaping the material to its final form for service. This enormous widening of the gap between raw material and finished structure has been making it more and more nearly impossible for any man to gain the familiarity with the material which would enable him to interpret successfully the vague criteria which were the original bases of materials testing. A new development of materials testing became necessary to meet the new situation.

The bases for this new development were laid in the same scientific progress which had given rise to the changed industrial conditions. Mathematicians and physicists had delved deeply into the laws which governed the strength and deformation of bodies under load. These laws gradually took on definite form and became more and more adequate representations of the phenomena, until finally in the mathematical theory of elasticity, supplementing analytical mechanics, engineers found a safe foundation for a theory of the mechanics of materials and their assemblages into structures of many diverse shapes.

Herein lay the possibility of the new development of materials and structural testing as an independent art that is rapidly changing into a science.

It became possible for the engineer to state that a material having certain definite measurable properties, objectively expressed in figures, built into a structure of a certain design, would be satisfactory under some given conditions of service. It was then possible for anyone skilled in materials testing, although he might not know the principles on which the structure was designed nor even the use for which it was planned, to state as a result of standard tests that material submitted did or did not have the required properties. Materials testing had become objective.

In spite of the progress in the theory of elasticity, great gaps are still left. For definite knowledge we are still almost wholly confined

to the region of "perfect elasticity," and only in the last thirty years has a beginning been made in the understanding of the behavior of bodies in the region beyond the nebulous limit which separates "elastic" from "inelastic" behavior. So incomplete is our knowledge of this structurally important region that we are still not sure just what are the conditions under which a material breaks. We know, of course, with considerable accuracy, the static tensile, compressive, and shear stresses which, acting alone, will cause the yielding or rupture of many materials, but in regions of complex stress distribution, we have not yet learned how the various stresses are to be combined into a single criterion of strength or if indeed any single criterion may be found. There have been many careful investigations of the action of combined stresses, but unfortunately all of them are open to various interpretations and even in particular cases leave us still uncertain, whether maximum stress, maximum strain, maximum shearing strain, or sometimes one and sometimes the other, or perhaps some complex function of some or all of them, are valid measures of the strength of the material.

Still less are we certain of valid criteria for the case of fluctuating or alternating stresses. Failures under varying load—both impact and fatigue failures and especially the latter—are still imperfectly understood. The advent of modern high-speed machinery has brought these failures into prominence, but the experimental work on them, the necessary basis for a valid theory, although started over fifty years ago, has really only just begun.

Some few things have been learned about fatigue failures and the lesson has in many cases been costly. We know, for instance, that in parts subjected to high alternating stresses sharp reentrant angles, rough or scratched surfaces, especially at fillets; and thin outstanding fins, should be avoided like poison. Unfortunately, there are still designers and constructors who have not fully learned this lesson.

We know, also, that vibration does not cause metals to crystallize, that the characteristic crystalline fracture found in fatigue failure merely means that the crystals of which all metals are formed have not been greatly distorted as they are in static tests and that the failure has taken place along planes of weakness either in the crystals or at their boundaries.

Although this has been known for many years, men who ought to know better still talk about failures of metals caused by crystallization.

Many other gaps in our knowledge of the mechanical properties of

materials and their significance could be enumerated if time permitted, but these two are sufficient to indicate how far we are from a complete understanding of the problems involved.

The statement of these limitations may make it seem as if we were still not far from the "rule of thumb" stage of the art. This is both true and untrue. In many materials tests we know definitely what properties of the material we are seeking to determine and in a general way the relations they bear to the use of the material. Such, for instance, are the tests for tensile and compressive strength, and moduli of elasticity. These properties bear direct, and in their broad outlines at least, definitely known relations to the strength and stiffness of any structure built of the material. They form, then, reliable and indispensable bases for judging the quality of the material, and we feel sure that they will endure in practically the form in which they are at present standardized as an essential part of the technic of materials testing.

Other tests are still largely on the "rule of thumb" basis, and sometimes it seems to me that there still clings to them somewhat of superstition. We make the tests partly because there are, or seem to be, correlations between the results of these tests and the quality of the material in service, but partly, also, because they are reputed to distinguish between some good material and some bad material, and we, in our ignorance, hesitate to give them up, in a justified fear lest we may be abandoning useful tests. In these tests we often have no clear idea as to what qualities of the material we are trying to determine, nor whether, if determined, they would bear any definite relation to the serviceability of the material.

There is a common characteristic of these tests by which they may be separated from the soundly established tests. They have not been even approximately standardized and new and variant methods of making them are continually proposed. In this class the cold-bend tests which are supposed to determine the "ductility" or "toughness" of a material furnish perhaps the most striking example. Their name is legion. Some of them, with some materials, for some uses, certainly are of value, but in many cases this value is, to say the least, doubtful.

We must not, however, condemn and abandon as useless time-honored tests, merely because we have not been able to remove them from the "rule of thumb" class and give them a sound theoretical basis. We need only remember the many "hardness" tests. "Hardness," as commonly thought of, represents a hazily conceived conglomeration or aggregate of fairly indefinite properties of a material,

more or less related to each other. They are usually, but not always, mechanical properties. They include such varied things as resistance to abrasion, resistance to scratching, resistance to cutting, ability to cut other materials, resistance to plastic deformation, high modulus of elasticity, high yield stress, high strength, absence of elastic damping, brittleness, lack of ductility and malleability, high melting temperature, magnetic retentivity, etc. This confusion under the one designation "hardness" results from the fact that there is a rough parallelism in these properties in a large number of materials. The fact that "hardness," thus conceived, is a conglomeration of different, more or less unrelated properties makes it impossible to correlate any one definite, measurable property with all the current implications of hardness.

This does not mean that under the hazy conglomeration of properties which are included in the common understanding of hardness, there are not included very important properties of the material.

Nobody doubts that the "hardness" of the diamond is one of its most important physical properties, nor that it is necessary to control accurately the "hardness" of metal-cutting tools or of balance knife edges, nor that the difference between "hard" and "soft" glass is of great technical importance, nor that there is a great difference between "hard" and "soft" woods or between "hard" candy and chocolate creams, a difference which is of considerable commercial importance.

It does, however, mean that the properties implied by the term "hardness" in these different cases are so heterogeneous that they cannot represent definite, accurately comparable properties of the materials in the sense that, for example, density, moduli of elasticity, specific heat, etc. represent definite and accurately comparable properties of the materials.

With all this haziness, the "file test" of hardness still retains its usefulness in the hands of a skilled mechanic.

Even more, a few indentation tests—so-called "hardness" tests—have been progressively standardized until finally they serve as powerful tools in ensuring uniformity in the quality of millions of pieces of metal. How general the practice is, I do not know, but every axle of a well-known make of automobile bears on it the characteristic dimple—the record of a Brinell indentation test—made to ensure that it was properly tempered. Nevertheless, we know so little about the test that we are not even able to give a reliable method applicable to all materials, for comparing 500-kg Brinell hardness with 3000-kg Brinell hardness.

Materials testing is still in its infancy and only by keeping in mind the purely empirical nature of many tests, continually searching for firmer theoretical knowledge and continually comparing the results of materials tests with the results of structural and service tests, can tests be either safely discarded or placed upon the sure foundation of theory. Fortunately for our hopes for the future, the last few decades have seen the beginnings of a promising attack on the theory of plastic deformation, the phenomenon which underlies so many of the ill-defined materials tests.

In a materials test the ideal striven for is to subject a portion of the material to definitely determinable stresses and observe its behavior under these stresses. If we had some means of applying forces at will to each element of volume in the interior of the specimen this ideal could be realized. There is, however, no way in which this can be done. Practically, we can only apply forces to the surface of the specimen and the resultant distribution of stress through the specimen is beyond our direct control, since it depends not only on the surface forces which we can control but also on the shape of the specimen and nature of the material under test. Similarly, our measurements of the deformation of the specimen are practically limited to surface deformations, and from these we infer, so far as possible, the distribution of strain inside. We can, however, in simple cases so shape the specimen and so apply the load that in limited portions of the material an approximation to the desired distribution of stresses is obtained. When this is well done the strain distribution in the interior may be reasonably well inferred from the surface deformations. The ideal, however, is never reached and it is only by painstaking design of the shape of specimen and arrangement of loading devices that a reasonably satisfactory test is ensured.

Much study has been given to the design of test specimens, of testing machines and their attachments, and of strain measuring devices, and a bewildering variety of apparatus has been developed, adapted to many different kinds of materials and sizes and shapes of specimen.

The improvement of materials testing technic in the last few years has been marked, but enough more remains to be done to tax the ingenuity of future generations of testing engineers.

THE PROBLEM OF NEW MATERIALS

New materials furnish one of the most interesting problems not only for the materials testing, but also for the designing engineer. If we knew definitely the meaning of all our materials tests in relation to

the material in service, materials tests alone would furnish a solution. As we do not, the best we can do is to subject the material to our customary tests, determine to the best of our ability the uses to which it is adapted, turn it over to the designing engineer, and then await the verdict of time.

This can be best illustrated by briefly considering a type of structural material which has been developed within the past twenty years and is now coming into fairly wide use. I refer to the light aluminum base alloys of which duralumin is perhaps the most familiar.

Duralumin, an alloy containing about 95 per cent aluminum and the remainder largely copper, magnesium, manganese, and silicon, has a tensile strength approximating that of ordinary structural steel, but a density approximately one-third as much. The modulus of elasticity approximates ten million pounds per square inch (one-third that of steel).

The obvious advantage of these alloys lies in their low density and high strength-weight ratios. However, equally high, and even higher strength-weight ratios are obtained from steels. We have alloy steels in billet form with tensile strengths up to 200,000 pounds per square inch and ordinary carbon steels in wire form show strengths higher than 250,000 pounds per square inch.

In tension members the same combination of strength and lightness can therefore be obtained with the cheaper well-tried materials, so that here the light alloys offer practically no advantage. In the airship Akron, for instance, the purely tension members are practically all high-strength steel wires.

The strength of a beam or column, or any structural member, in which compressive stresses play a significant part, depends not only on the strength of the material and the area of the cross-section, but also on the linear dimensions of the cross-section and the modulus of elasticity of the material. Within limits, the further the material can be removed from the centre of the cross-section the stronger the member. This accounts for the familiar H and box sections of columns, and the tubular construction of bicycle frames and the fuselages of many airplanes. The limits are set by the fact that as the material is further removed from the centre of the cross-section, it necessarily is made thinner. If too thin, it crumples under compression somewhat like a sheet of paper. This crumpling depends practically upon the thickness and the modulus of elasticity, and only in small measure on the strength of the material.

In duralumin the strength-weight ratio is equal to the best of the alloy steels (except in wire form) and its modulus-weight ratio is practically the same, so that roughly speaking for the same outside linear dimensions of cross-section equal weights of material would make equally strong beams or columns. The flanges, webs, and walls of the duralumin structures would, however, be approximately three times as thick as the steel, so that the outside linear dimensions of the cross-section could be increased, with diminishing thickness of wall, without danger of crumpling. Consequently, either lighter or stronger structures can be made of duralumin. Obviously this is one of the most advantageous fields of application of these light-weight alloys. The correctness of this conclusion is attested by their successful use in airship girders and airplane beams.

With the determination of this advantageous field of application the problem of their economic use is still not solved. In spite of notable progress during the last forty years, the theory of compression members remains in an unsatisfactory state, and we are not yet able to reason with absolute certainty from the strength of one column or girder to another of similar design but of radically different dimensions. The uncertainty becomes greater when we change to materials with markedly different relations between stress and strain.

The application of these alloys has, therefore, been a slow process of successive improvement in design, continually checked not only by materials tests but even more by structural tests, until today for certain uses certain types of design seem to be approaching standardization. When we consider that the duralumin girders of the Shenandoah, strong and light as they were, developed only about 60 per cent of the strength theoretically available in the material, and the girders of the Akron of markedly better design only make use of about 80 per cent, we can see that there are still opportunities for the designing engineer. Will it be found economical, for instance, in spite of its high cost, to use duralumin in the construction of long span bridges? It is an interesting speculation which has been seriously discussed.

So far, I have mentioned only the results of the better understood materials tests in judging this relatively new material. What of the others? One example will have to suffice. For the usual high-grade structural duralumin an extension of 18 per cent in two inches is specified. Why? For some of the new modifications extensions as low as 12 per cent are considered satisfactory. Why? We specify about 25 per cent for ordinary structural steel because we feel that smaller elongations indicate material less secure against shock and fatigue

failure as well as more difficult to fabricate, and 25 per cent is readily obtained commercially. It is hardly safe to reason by analogy from steel, for we have to do with an entirely different material. This is clearly shown by the age-hardening properties of duralumin, which make the practical difficulties of its fabrication so different from those of steel. By lowering the specified elongation of duralumin to 12 per cent, material is now furnished for special purposes up to 75,000 lb. per sq. in. tensile strength instead of 55,000 to 65,000 lb. per sq. in. which was formerly considered the best that could be furnished commercially.

These newer, higher strength alloys with lower elongation, developed to meet specific demands, introduced and used with many misgivings, have so far proved to be satisfactory in service. It is still too soon to predict the ultimate judgment which will be passed on them.

Could elongations even lower than 12 per cent be specified with safety? Who can say?

A new material, however desirable its qualities, must thus pass through a period of probation before designs are worked out which will use these properties to the best advantage. In this probationary period structural tests furnish one of the most valuable aids to rapid progress. Even materials which have been much longer known and used, have as yet not wholly passed this probationary period, so that structural tests on so well-known a material as ordinary structural steel are still teaching us how it may be used to better advantage.

STRUCTURAL TESTS

In principle the structural test differs markedly from the materials test. In the materials test the object is to study the behavior of the material under the action of known stresses. In the structural test the object is to study the behavior of a given structure or structural part under the action of known loads, usually approximating those it is designed to be subjected to in service. In their practical carrying out no such distinction can be drawn, and they grade insensibly one into the other. The known stresses are produced in the materials test specimen by the application of a known load to a given shape of the material. The shape of the specimen and the character of the load are so chosen as to produce the desired stress. Obviously if a structure is so shaped and loaded as to have the same stress as in the materials test, the structural test is a materials test as well. A tensile test of a piece of wire or belting, for instance, is either a materials or a structural test, depending upon the viewpoint.

In testing practice the difference lies chiefly in two things. First, in structural testing, the size and shape of the specimens and type of loading cannot be changed at will, but are determined by considerations of design. The loading devices may thus have to be much larger and more powerful, as well as more complex, than is necessary in materials testing. Second, a major feature of the test may be the determination of the stress and strain distribution in the structure, necessitating an elaborate provision of strain gages. In an investigation of riveted joints for the Bureau of Construction and Repair of the Navy Department, fourteen sensitive optical strain gages, as well as a number of other measuring devices, were used on a single test specimen.

In an investigation of girders for the U.S.S. Shenandoah 81 dial micrometers were used on a single test specimen.

MODEL TESTS

Obviously the size of the available testing machines, as well as the large cost, sets a practical limit to the size of structures which can be tested. Model tests offer in many cases a possibility of effectively overcoming this limitation. From the law of similarity we know that if geometrically similar structures of different sizes, fabricated in all their details of identical material, are subjected to geometrically similar static load distributions, the stress and strain distributions will remain geometrically similar even beyond the elastic range and up to failure of the structures. We can, therefore, reason directly from a model to a structure of any size. Unfortunately, simple as this theory is, its practical application is beset with difficulties. No large structure is formed of homogeneous materials. Rolled plates and angles vary in properties over their cross-section and the law of this variation is different for different sizes, and is different for different portions of the ingot from which they are rolled. The rivets or welds with which they are united are of different quality from the rolled sections which they hold together and this difference is often important for the success of the structure. It is, if not impossible, at least extremely difficult to choose materials for small rivets which will show the same properties after cooling as the large rivets. It is also practically impossible to produce small welds with the same physical characteristics as larger welds. The technical limits of accuracy in fabrication also set a limit to the size of a structure which can be reproduced in detail in a model of convenient size. In so far as these differences in detail are of significance in the behavior of the structure, model tests have only a limited field of application. This may be illustrated by the investigation of

riveted joints carried out for the U. S. Navy. The whole problem here lay in the most economical choice of rivet material and rivet arrangement in the use of the newer high-strength ship plates. As our largest tension machines have a capacity only slightly over a million pounds, we can, in a full-size specimen, test a row only four or five rivets long. The stress distribution in so short a row will certainly be different from that in a corresponding part of a row many feet long, but this uncertainty was felt to be less important than the difficulties involved in producing a comparable half or third size model. It seemed almost certain that a model, even roughly comparable, could not be produced.

In addition, the local concentration of stresses and strains in the neighborhood of structural discontinuities are often critical factors in determining the design. The measurement of these stresses and strains demands a detailed study of local deformations, which even in full-size structures often lie near the limit of sensibility of our strain gages. In the model these deformations will be proportionately smaller, requiring for their detection more sensitive devices. An optical strain gage, developed at the Bureau of Standards in connection with this riveted joint investigation, has permitted a considerable extension of the possibilities of model testing.

In its present form on two-inch and one-inch gage lengths it can be relied upon to detect consistently, deformations as small as two or three-millionths of an inch and its compactness and light weight make it probable that it can ultimately be adapted to much shorter gage lengths—perhaps as low as one-fourth inch.

If the tests are concerned merely with the behaviour of the structure within the range where the deflection of the members as a whole is practically proportional to the load, many of these difficulties of model testing, which have been pointed out, disappear, since then the details of joints need to be reproduced only in rough similarity, and built-up members can be safely replaced by solid pieces of similar shape. The strength of the parts no longer being a factor in the test, practically any piece of approximately the same material (or where the difference in Poisson's ratio is not significant, any material) will serve, since the moduli of elasticity differ but slightly for widely different qualities of material.

In addition, if the members of the structure all lie nearly in the same plane so that the stress is approximately a plane distribution, any elastic material whatever may be used, since in plane stress the stress distribution is independent of the moduli of elasticity. Much

use has recently been made of this fact in determining the stress distributions in structures (such, for instance, as massive arches) in which the mathematical treatment is difficult, if not impossible.

No discussion of model tests, however brief, would be adequate without mention of one of the most fruitful methods of model testing —optical stress analysis by the use of polarized light. Discovered over 100 years ago, its theory and the fundamental experimental methods were worked out nearly seventy-five years ago, but until the last few years it remained largely a laboratory curiosity. I need not elaborate on the remarkable developments of the last few years. Complex stress distributions in structures of complex geometrical shape—for example, a pair of meshing spur gears—are now known with a wealth of detail that twenty years ago would have been thought impossible. I merely wish to point out the relations of the method to the general field of materials and structural testing. Optical stress analysis possesses a sensibility that no mechanical strain gage can ever hope to reach. On small models it can trace out details of stress distribution around discontinuities of structure, which could only be detected in gigantic models by any mechanical strain gage we can ever hope to construct. Within its limitations it furnishes, beyond any comparison, the best method of model testing.

Unfortunately, its limitations are narrow. It requires a transparent model, and no known transparent material has a Poisson's ratio which is the same as that of any ordinary structural material. Its application to model testing is therefore limited, strictly speaking, to cases of plane stress or those which approximate plane stress, for only in such cases can we reason directly to the stress distribution of similar structures with other values of Poisson's ratio. Even were it possible to use the method in more complicated stress distributions the experimental difficulties would probably be too great to make it practical. However, by judicious use of the results of plane-stress analysis it has been possible to draw valuable, although approximate, conclusions about widely different conditions.

SERVICE TESTS

After all, "the proof of the pudding is in the eating thereof." Materials tests, design, and structural tests all look towards one goal—a structure in satisfactory service. The difficulty lies in determining what is satisfactory service. For bridges, dams, buildings and other structures whose conditions of use are fairly definite the answer is relatively simple. For other structures, especially those containing

many moving parts, the conditions of service are so diverse that no valid criterion of satisfactory service can be obtained from a single case. Two automobiles are turned out from the same shop on the same day. One is a wreck inside of a season, while the other may be still in service years later. That does not necessarily indicate that the first was not properly constructed to render satisfactory service; its condition may have been due to gross abuse. Nor does it necessarily indicate that the second was properly constructed. It may have had only a fraction of the use that should be expected of it. It is evident that in general only a statistical study of many individual service records can furnish results that are significant.

Where the finished structures remain under centralized control in use, the maintenance of reliable statistics of service is possible. Such statistics where available are a sound basis for a final judgment on all questions of the use of materials.

In the larger number of cases the use of the finished structures is in the hands of innumerable individuals under no centralized control, so that the securing of reliable service statistics is difficult, if not impossible. Also, even when available, service statistics are slow in accumulating. Where production is large, many thousands of unsatisfactory products might be put out into service before any service statistics could show the points in which they were unsatisfactory.

The service test, or—more accurately stated—the accelerated service test, is an attempt to bridge this gap. After a study has been made of all the imaginable deteriorating influences which the structure is likely to be subject to in use, an attempt is made to determine their average frequency of occurrence and their average importance in causing failure of the structure. By means of this study a program of abuse is outlined which is designed to cause failure within a time which is only a small fraction of the normal life in service. The abuse may consist of exaggerating the severity of the normal deteriorating influences of service or increasing the frequency of their occurrence, or a combination of both.

The comparative life of structures under well-planned abuse furnishes within a relatively short time a not altogether perfect but still valuable substitute for service statistics. Perhaps the best known examples of such tests are the intensified traffic tests carried out on test roads by the Bureau of Public Roads and the Highway Departments of various states. These tests are helping greatly in the improvement of road construction.

The value of such tests, obviously, depends in large measure upon

the judgment used in planning the program of abuse. Only if the test does fairly represent a proportional exaggeration of all the deteriorating influences in average service, will the test results correlate closely with service statistics.

SPECIFICATIONS

Much of the work of the materials and structural testing engineer would fail of its effectiveness if it were not crystallized into definite form for routine use. Accordingly, specifications are written.

If all were known that should be known about materials and their relations to structures, it is conceivable that specifications could be written which would meet the wholehearted approval of the manufacturer, the user, and the testing engineer. As it is, specifications represent a compromise between all three, based partly on knowledge, partly on ignorance, partly on habit, and partly on traditions of the art which may or may not be well founded. As a consequence no one is fully satisfied.

Unsatisfactory as they are we could not do without specifications. Of what use would it be to a builder to know that steel of given physical properties built into a given structure would not collapse under its load, if he had no assurance that the material furnished him had these properties? How could a manufacturer of steel be in a position to furnish satisfactory material to a builder unless the builders' requirements were so formulated as to be applicable to the control of his mill processes? Without the thousands of specifications which are intimately woven into it, modern industry could not function.

Even though we recognize that most specifications are, in many ways, unsatisfactory, there are still good specifications and poor specifications. Good specifications foster cooperation between manufacturer, user, and testing engineer in the production of satisfactory structures and their progressive improvement. They are a thorn in the side only of the man who would sacrifice quality to his own personal profit.

Poor specifications lead to endless controversy and misunderstanding even between those who are anxious to cooperate in the production of satisfactory structures.

An important part of the work of the materials and structural testing engineer is the assistance he gives in the improvement of specifications to the end that all may be good specifications. If he is called upon to write or assist in writing specifications, he must add to his testing technic much of the technic of specification writing, which is a related but distinct art.

Even if he personally does not write specifications, a testing engineer should have a clear understanding of the principles which govern specification writing so that he may recognize the difference between a good and a poor specification.

Many of our specifications would be better, many of the controversies which arise between manufacturers and users would be avoided if more testing engineers, and especially specification writers, familiarized themselves with these principles and followed them.

In 1907 the French engineer, Georges Charpy[3] whose name is familiar to all who test metals and who has contributed so much to modern materials testing technic, formulated clearly a principle which, it would seem obvious, should, so far as possible, govern all specifications.

"Toutes les conditions imposées doivent être spécifiées avec assez de netteté et de précision pour que chacune des deux parties (le producteur où le consommateur) puisse les vérifier sans ambiguité à un moment quelconque . . ."[4]

In the years that have passed since Charpy wrote these words, more and more engineers have heeded them, and specifications today are on the average far superior to those written twenty-five years ago.

Nevertheless, in a specification written in 1931 and still in use, I find the following requirements for a certain structure:

"Size, 1 in.; outside dimensions (approximate) 5 in. by 3¼ in.; weight, per dozen, 40 lb.; tensile strength (approximate) 70,800 lb. per sq. in."

Samples of this structure are sent to a testing laboratory with the request that a report be given stating whether the structure does or does not meet the requirements of the specification. What is the poor testing engineer to do? Is 5¼ in. by 3 in. approximately 5 in. by 3¼ in. or should the tolerance be set closer? Are 39 lb. or 41 lb. acceptable weights? If so, what about 35 lb. or 45 lb.? Was it the intention to set a minimum or a maximum tensile strength? Is 65,000 lb., 70,000 lb. or 75,000 lb. a sufficiently close approximation to 70,800 lb. so that he may say that it does or does not meet the requirements? As a testing engineer he knows how to determine—within all reasonable accuracy—what the dimensions are and what the tensile strength is. Must he also, in order to be competent, know what limits of dimensions or limits of tensile strength ought to be set on a structure he may never have used or even never have seen before?

[3] CHARPY, GEORGES. *Les cahiers des charges pour la réception des matières métalliques.* Revue de Métallurgie, Mémoires 4: 1041–1058. 1907.

[4] "Every specified requirement ought to be specified with sufficient clearness and precision, that each of the two parties, (producer or consumer) may at any time determine unambiguously whether the requirement is met."

Such a clause in a specification is an invitation to argument, dispute, hard feelings, and even litigation. It violates a fundamental principle of specification writing.

Contrast it with the following:

		Minimum	Maximum
Size		31/32 in.	1-1/32 in.
Outside dimensions	Length	4-7/8 in.	5-1/8 in.
	Width	3-1/8 in.	3-3/8 in.
Weight, per dozen		39 lb.	41 lb.
Tensile strength		70,800 lb./sq. in.	No maximum specified

This does take a little more printing ink than the other but with such requirements no testing engineer would quarrel. Whether these are suitable limits for the structure specified he might not know: he does not need to know. The limits acceptable to both producer and consumer should be set by the specification writer. He should not ask the testing engineer to exercise his talent for guessing or telepathic mind reading.

This is merely a flagrant illustration of one way in which a poor specification differs from a good one. Many more could be cited. No great technical skill is needed to banish such defects—merely a determination on the part of the writer of the specification to avoid obvious indefiniteness and ambiguity.

To search out the defects in good specifications, to change them so that their meaning is more clear, to modify the test conditions so as to make the tests cheaper without sacrifice of quality, to fit them to progressive advances in manufacturing processes, in other words to make better specifications out of good specifications—this is a task which challenges the skill of the best of testing engineers.

I cannot better end this brief consideration of specifications than by quoting again from Charpy—a master in the art of writing specifications. He lays down the following canon[5] of basic requirements of a good specification:

"Suppression de toutes les clauses vagues, ne permettant aucune vérification précise et laissant en réalité place à l'arbitraire.

"Réduction aussi grande que possible des conditions de fabrication qui peuvent, le plus souvent, être remplacées par des conditions de qualité.

"Définition minutieuse et précise de tous les essais qui doivent servir à vérifier les différentes conditions de qualité. Spécification du nombre des essais, des cas où ils pourront être recommencés.

"Etablissement d'une corrélation entre la précision des machines d'essai (et sa vérification) et la précision demandée dans les résultats des essais.

[5] CHARPY, loc. cit.

"Emploi de prescriptions combattant la fraude dans toutes ses manifestations."[6]

The last clause should not be necessary but unfortunately the specification writer dare not forget it.

CORRELATION OF MATERIAL, STRUCTURAL, AND SERVICE TESTS

The development of materials testing as an independent art was made possible by the scientific development which freed it from its intimate association with a unified process of manufacture. Only through that freedom could it become objective and quantitative. That freedom, however, is not complete and has brought with it, as every partial freedom does, not only good but bad effects. Busied with the details of testing, the testing engineer is too likely to think of the results of his tests as ends in themselves, independent of their relation to material structures in service. This tendency can only be combated by seeking continually and consciously to correlate the results of materials, structural, and service tests, one with another, and in the last analysis with statistics of service. With fuller understanding of these correlations, materials and structural testing will contribute still more to the progress of engineering. With this fuller understanding, materials testing will become more and more a science, approaching the ideal in which, from materials tests alone, the field of usefulness and serviceability of a material may, with certainty, be determined, to the end that there may no longer be pitfalls on the path from material to structure.

[6] "Suppression of all vague clauses which do not permit any precise verification, and which actually leave room for arbitrariness.
"Reduction to a minimum, of limitations on the processes of manufacture, which can usually be replaced by quality requirements.
"A meticulous and precise prescription of all the tests which serve to determine the quality. Specification of the number of tests and of the cases in which retests will be allowed.
"Specification of a relation between the precision of testing machines (and their verification) and the precision required in the results of the tests.
"Use of proper prescriptions to prevent fraud in all its manifestations."

GEOLOGY.—*Geologic reconnaissance of a region adjacent to Guantanamo Bay, Cuba.*[1] O. E. MEINZER, U. S. Geological Survey.

PURPOSE AND SCOPE OF THE RECONNAISSANCE

This paper is based on observations by the writer during a field investigation which he made, as the representative of the U. S. Geolog-

[1] Published with the permission of the Director, U. S. Geological Survey. Received January 7, 1933.

ical Survey, for the purpose of finding a water supply for the United States naval station at Guantanamo Bay, Cuba. The investigation covered a period of six weeks in the fall of 1915, and was chiefly devoted to a detailed study of the geology of the United States reservation, which is a tract about 9 by 5 miles in extent, embracing the lower part of the bay (see Fig. 1), and to the location of well sites and the sinking of test wells on the reservation. A reconnaissance was, however, made eastward along the coast to the Imias River and up the Yateras River to Yuraguana (see Fig. 2).

The writer is indebted to T. Wayland Vaughan and C. Wythe Cooke for examining the fossils that were collected and for advice regarding the correlations of the several formations. Doctor Vaughan has recently (1932) revised the identifications of the foraminifera and corals and has kindly prepared the lists of species appended to this paper.[2]

Topography

The region bordering the south coast of Cuba between Cape Maisi, at the east end of the island, and Cape Cruz, about 260 miles farther west, is in general mountainous, the principal interruption in the mountain chain being at Guantanamo Bay, 75 miles west of Cape Maisi. Near its head this large, pouch-shaped embayment is bordered by an extensive lowland plain, on the east, north, and west sides of which the mountains rise somewhat in the form of a huge amphitheater. Near its mouth the bay is, however, constricted by belts of foothills that extend toward the bay from the mountains on both sides.

The United States reservation lies on both sides of the lower part of Guantanamo Bay, the east side being the larger and having nearly all the development. There are three principal types of topography on the reservation: (1) hills and ridges with small intervening valleys, (2) terraces, and (3) lowlands, or tidal flats, more or less continuous with the extensive lowland at the head of the bay.

The principal hilly area, known as the Cuzco Hills, is in the southern part of the reservation, on the east side, and it forms the greater

[2] The fossils are described in the following publications:

Cooke, C. Wythe. *Tertiary mollusks from the Leeward Islands and Cuba.* Carnegie Inst. Washington Pub. **291**: 103–156. 1919.

Cushman, J. A. *Fossil Foraminifera from the West Indies.* Carnegie Inst. Washington Pub. **291**: 21–71. 1919. Also *The American species of* Orthophragmina *and* Lepidocyclina. U. S. Geol. Survey Prof. Paper **125**: 39–105. 1920.

Vaughan, T. W. *Fossil corals from Central America, Cuba, and Porto Rico, with an account of the American Tertiary, Pleistocene, and Recent European Tertiary larger Foraminifera.* Geol. Soc. Amer. Bull. **35**: 785–822. 1924. Also *Species of* Lepidocyclina *and* Carpenteria *from the Cayman Islands.* Quart. Jour. Geol. Soc. London **82**: 388–400. 1926.

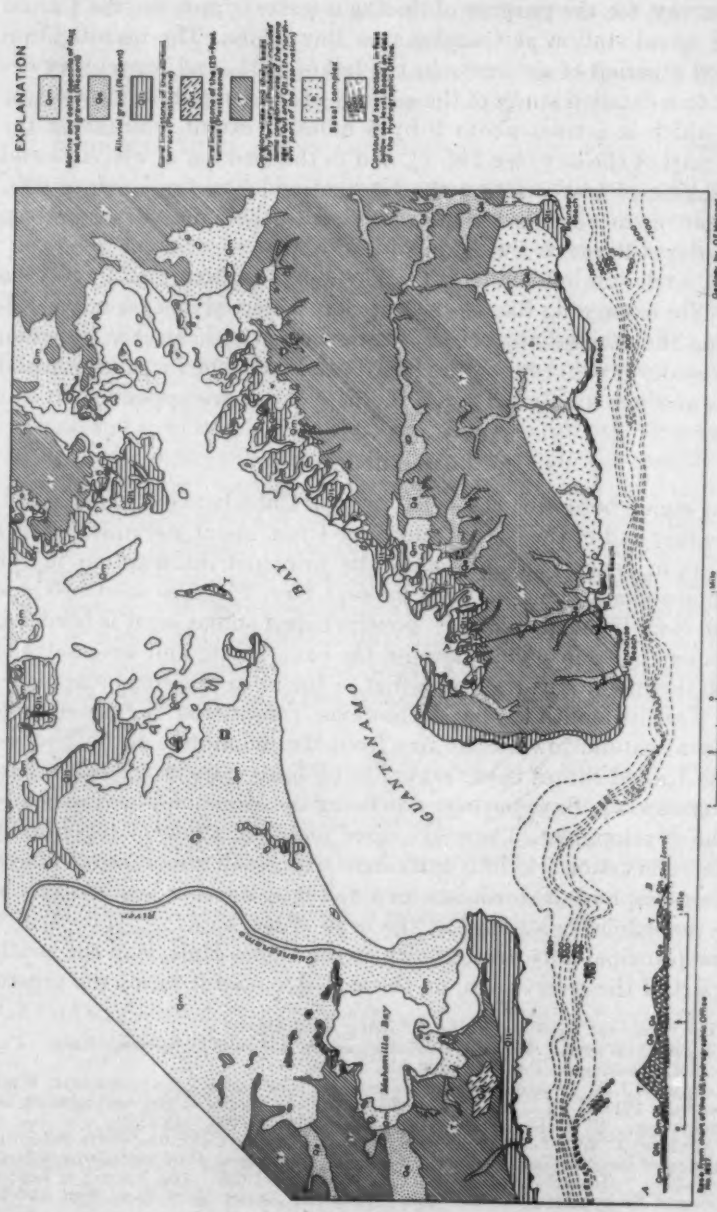


Fig. 1.—Geologic map of the U. S. Reservation, Guantanamo Naval Station, Cuba.

part of a peninsula about 5 miles long and 1 to 3 miles wide, projecting westward between the Caribbean Sea and Guantanamo Bay (Fig. 1). Its ridges, or rows of hills, trend in a direction somewhat south of west. Many of the hills rise more than 300 feet above sea level, and the highest point, known as Paul Jones Peak, is 494 feet above sea level.

There are two terraces on the reservation, which will be designated respectively as the 40-foot terrace and the 125-foot terrace, although the actual elevations vary considerably. These are described later.

The principal lowland area on the reservation is the large delta of the Guantanamo River, in the northwestern part, which has protruded into the bay, practically isolating the waters of Mahomilla Bay and the very shallow salt lake farther north. Lowlands also border the bay on the east side, forming tidal flats, especially in the reentrants of the 40-foot terrace. On the map (Fig. 1) the mangrove tracts, which are slightly below sea level, are included with the land areas.

East of the reservation the ridges assume the proportions of mountain ranges. The culminating point of Los Melones Mountains, less than 2 miles from the reservation, is 1,108 feet above sea level, and the crest lines of the other ranges immediately east of the reservation are in general not far from 1,000 feet above sea level. Farther east the mountains are still higher, many of the peaks between the Sabanalamar and Imias Rivers reaching altitudes of 2,000 to 4,000 feet. The ranges are in general more or less parallel with the coast and are separated by rather wide structural valleys. The principal streams for the most part cut across the ranges in relatively narrow valleys bordered in many places by high bluffs.

East of the reservation, between the Yateras and Imias Rivers, and no doubt still farther east, a series of terraces is well developed, not only along the coast but also in the interior structural valleys. The most conspicuous terraces are at levels of approximately 40, 200, 500, and 750 feet.

CLIMATE AND VEGETATION

The region adjacent to Guantanamo Bay has a mild, equable, oceanic climate, like that of other parts of Cuba, but, owing to the persistent trade winds and to the mountain barriers, it differs from the greater part of the island in being semi-arid. The average annual precipitation during a period of a little over three years (1912–1915) was about 17 inches. The principal rainy season is in the fall, and a

Fig. 1.—Geologic map of the U. S. Reservation, Guantanamo Naval Station, Cuba.

secondary rainy season occurs in the spring. The season of greatest aridity is the summer. Although the precipitation is light the humidity of the atmosphere is high, and consequently the very moderate lowering of the temperature at night is generally adequate to produce a heavy dew.

The peculiarities of the climate are reflected in the native vegetation. The region abounds in large cacti and other desert plants, not unlike those found in southwestern Arizona, but in addition it has in most places a dense growth of bushes and dwarfed trees, chiefly hard woods, forming almost impenetrable thickets. Moreover, certain tall grasses grow luxuriantly in localities that do not have any special water supply. One of the most characteristic trees of the region is a small palm, known as the yuraguana, which predominates on dry, exposed limestone ledges. The large luxuriant palms grow only along the streams and in other shallow-water areas and appear to be dependable indicators of ground water.

The high humidity and warm climate are favorable to rapid decomposition of the rocks, whereas the light rainfall provides only feeble instruments of stream transportation. Consequently the region is characterized by a great abundance of rock waste, even on steep hillsides, and good rock exposures are not common except along the coast, where the waves are effective agents of erosion.

The country between Guantanamo Bay and the Imias River is sparsely settled, resembling similar regions of rough topography and dry climate in the western part of the United States except that stock raising is carried on less extensively and less systematically. The few inhabitants of the region live near isolated springs or small streams, where they cultivate garden plots and raise a few domestic animals. As in the arid parts of the United States, the traveler must plan his itinerary with regard to available watering places.

GEOLOGIC FORMATIONS

Outline of stratigraphy

The rocks in the region examined comprise the following four divisions, arranged in the order of their age, the oldest being given first:

1. A basal complex of metamorphic and igneous rocks of unknown age.

2. Tilted beds of conglomerate, limestone, shale, and impure sandy and marly materials, several thousand feet in aggregate thickness (chiefly Oligocene; Eocene at bottom and possibly as young as Pliocene at top).

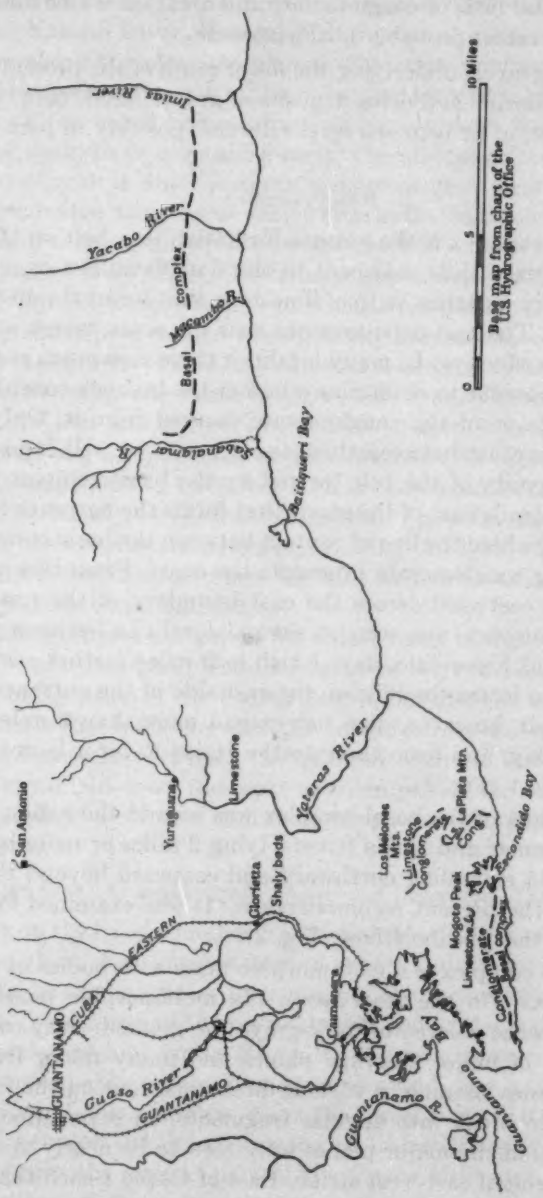


Fig. 2.—Map of the region between Guantanamo Bay and the Imias River, Cuba.
Covered in geological reconnaissance by O. E. Meinzer.

3. Horizontal beds of conglomerate and coral limestone underlying a series of terraces; probably all Pleistocene.

4. Stream gravels underlying the lower parts of the present stream valleys, and marine and delta deposits of gravel, sand, mud, and calcareous debris, at or near sea level (Recent; possibly in part Pleistocene).

Basal complex

The basal complex is the surface formation in a belt on the south side of the Cuzco Hills, adjacent to the Caribbean Sea or separated from it by only a narrow strip of limestone that forms the 40-foot terrace (Fig. 1). The best exposures are near the coast, where wave erosion has been effective. In many localities there is so much rock waste that it is impossible to determine whether the bedrock consists of the basal complex or of the conglomerate derived from it. Only at the coast is the contact between these two formations well exposed. The western extremity of the belt formed by the basal complex is about three-fourths mile east of the strait that forms the entrance to Guantanamo Bay, where the line of contact between the basal complex and the overlying conglomerate intersects the coast. From this point the belt extends eastward across the east boundary of the reservation. The basal complex was seen at several localities between the east boundary and Escondido Bay, which is 2 miles farther east, and it probably also forms the hills on the east side of the entrance to that bay. This belt, however, does not extend more than 2 miles east of Escondido Bay, and from there to the Imias River it is not exposed along the coast (Fig. 2).

A larger area of the basal complex was seen in the region between the Sabanalamar and Imias Rivers, lying 2 miles or more back from the coast and extending northward and eastward beyond the region covered by the present reconnaissance. It was examined for several miles along the Yacabo River (Fig. 2).

The basal complex is a metamorphic mass with bodies of intrusive igneous rocks. On the reservation the metamorphic mass consists chiefly of bronze-colored or dark-gray, fine-grained, slaty rock which has one set of major cleavage planes and many minor fracture or cleavage planes running in various directions, causing the rock when weathered to break into angular fragments. In several localities on the reservation the major planes were seen to be nearly vertical and to have a general east-west strike. East of Cuzco Beach they dip 75° S. 35° W. In some places, however, the cleavage planes are greatly

contorted and the formation appears schistose. True schist outcrops along the Yacabo River. In some places veins of quartz and gypsum (?) occur along the cleavage planes. The copper mines or prospect holes on the reservation are in the metamorphic rock. On the reservation only a few small bodies of intrusive rock were seen, and these consist of dark, basic crystalline rock. The abundance of boulders of this kind of rock in the overlying conglomerate indicates, however, that larger bodies must occur somewhere in the basal complex. Along the Yacabo there are intrusive bodies both of dark crystalline rock and of granite. Hard, dark, bluish limestone was seen a short distance east of Windmill Beach, but its relations were not determined.

The basal complex consists of sufficiently indurated rock to produce a rugged topography where it is exposed to erosion—the boldest and highest cliffs along the coast being in this rock. The hills which it forms in the belt on the reservation are not as high as those formed by the overlying conglomerate and limestone in the same region, but the mountains 2,000 to 4,000 feet high in the region farther east consist at least largely of the basal complex. The hills and mountains formed of these rocks are irregular, showing but little of the parallel arrangement that characterizes the hills and mountains formed by the conglomerate and limestone.

The basal complex comprises the oldest rocks in this region. In its induration and metamorphism it resembles the pre-Cambrian rocks found in many parts of the United States, but all that was definitely determined is that it is older than the conglomerate that underlies the Oligocene limestone and rests on the basal complex. Before the conglomerate was laid down the rocks now comprising the basal complex were extensively deformed and metamorphosed and then eroded to great depths.

Tilted beds of conglomerate, shale, and limestone (Tertiary)

Resting on the basal complex is a thick series of tilted conglomerate, limestone, shale, and various impure sandy and marly beds. These formations lie at the surface over most of the region examined.

Both in the vicinity of the naval station and in the region between the Sabanalamar and Imias Rivers hard ferruginous conglomerate rests unconformably on the basal complex and dips away from the exposed core of this complex. Near the naval station it dips northward and between the Sabanalamar and Imias Rivers it dips southward. It forms the greater part of the Cuzco Hills and outcrops in other localities on the reservation.

The conglomerate that comprises the lower part of this series is a dark brownish or reddish, dense, impervious, and thoroughly indurated formation. It has irregularities in texture but shows a definite and persistent although rude stratification. Boulders a foot or more in diameter are rare, and most of the large boulders are found near the base of the formation. Well-rounded pebbles ranging from a fraction of an inch to several inches in diameter make up a large part of the formation. The pebbles and boulders consist chiefly of slate and dark, basic, crystalline rock derived from the basal complex. Limestone pebbles were not found in the lower beds but at higher horizons the conglomerate contains limestone pebbles many of which are well rounded. On the south side of the Cuzco Hills, where wells were dug into valley fill derived from the lower beds of the conglomerate, no limestone pebbles were found, but the ridge farther north is composed of conglomerate beds in which there are numerous large and rather well-rounded limestone boulders. Many of these boulders contain fragments of fossils, none of which could, however, be identified. On the south side of Mogote Peak the conglomerate near its contact with the overlying limestone consists of well-rounded pebbles among which no limestone pebbles were found. The conglomerate in the extensive outcrops farther north and east, underlying the limestone of Los Melones and La Plata Mountains (Fig. 2), is in general non-calcareous but a few well-rounded limestone pebbles were found in it.

Resting on conglomerate at Mogote Peak and at La Plata and Los Melones Mountains there is limestone which has about the same dip as the conglomerate—generally between 10 and 20 degrees. Most of the region extending north in the vicinity of the Yateras River and east to the Sabanalamar River is underlain by limestone. Toward the north and east the dip diminishes in general until the beds lie nearly horizontal. At the mouths of the Macambo, Yacabo, and Imias Rivers the beds dip southward—away from the basal complex exposed in that region. There are many minor flexures involving some steep dips and even overturned folds, as at one locality on the Yateras, 2 or 3 miles south of Yuraguana. Faulting is suggested along the south side of Los Melones Mountains by the exceedingly precipitous south front of these mountains, and the escarpments of other ranges may be fault scarps.

The hard massive limestone that rests on the conglomerate in Mogote Peak contains fossils that are regarded by Vaughan to be of Eocene age. The fossils collected from the limestone in the vicinity of La Plata and Los Melones Mountains and farther northeast con-

tain fossils that are regarded by Vaughan to be of Oligocene age—at or near the horizon of the Antigua formation. The fossils were taken in several localities, for the most part from rock in place and some of them close to the underlying conglomerate. It was supposed in the field that the conglomerate at the base of La Plata and Los Melones Mountains was the same as that at the base of Mogote Peak and that the limestone contact was at the same horizon as that in Mogote Peak. It appears now that this conglomerate lies between the Eocene and Oligocene limestones.

In the northern part of the United States reservation the conglomerate beds give place largely to shaly beds that lie more nearly horizontal or even dip southward. A large part of the lowland north of the reservation, into which Guantanamo Bay extends, appears to be underlain by shaly and marly beds that dip at an angle of only a few degrees toward the east. An old test well, 1,400 feet deep, drilled in the northern part of the reservation went through 400 feet of alternating beds of conglomerate and shale and then through 1,000 feet of what was designated as "slaty shale," in which the well ended. East of the lowland is a conspicuous escarpment formed by limestone with some interbedded shaly strata, that rests on the main body of shaly beds. This limestone extends to the Yateras and furnished the Oligocene fossils that were collected near that stream east of Glorietta. The relation of the shaly beds to the other formations is uncertain but it seems probable that at the time of their deposition great local differences existed in the character of the sediments that were laid down.

The tilted beds that are exposed near the mouths of the Yateras, Sabanalamar, Macambo, Yacabo, and Imias Rivers differ from the formations that have been described as occurring between the naval station and the Yateras River, both in their lithologic character and in the fossils that they contain. They consist chiefly of interstratified beds of limestone and conglomerate with calcareous matrix, very different from the conglomerate already described. The limestone is in general soft and friable and in many places contains imbedded pebbles. All gradations between true conglomerate and true limestone can be found. The conditions under which these beds were formed were apparently similar to those found along the coast where calcareous debris is at present being deposited. According to Vaughan the fossils collected at several localities, especially those near the mouths of the Yacabo and Imias Rivers, appear to be of the age of the Santiago marl—an Oligocene formation younger than the Antigua formation. Fossils of possible Pliocene age were obtained in two localities from

what were regarded as tilted beds in place. Their evidence is inconclusive but points to the close of the Tertiary period as the time of the deformation of the Tertiary formations.

Terrace formations (Pleistocene)

Among the most conspicuous features of the region are the sea terraces, of which at least seven were observed at successive elevations up to about 750 feet above the present sea level. Of these, four are well developed in the region between the Yateras and Imias Rivers, and two are well developed west of the Yateras. The four east of the Yateras are at altitudes of approximately 40, 200, 500, and 750 feet above sea level—the figures for the lowest two being based on hand-level measurements, those for the upper two on rough estimates. The two west of the Yateras are at altitudes of approximately 40 and 125 feet, as determined by the topographic map and by hand-level measurements. In the vicinity of Guantanamo Bay the highest terraces are absent or indistinct. The 125-foot terrace appears to rise gradually toward the east and may be identical with the 200-foot terrace observed farther east.

The terraces generally slope gently from their landward to their seaward sides, owing both to their original grades and to the recent deposition of sediments on their landward sides. The altitude assigned to each respective terrace in this report is, as nearly as known, that of the unmodified sea bench at its landward margin, which represents approximately the level at which the sea stood when the benches were formed. Thus the so-called 40-foot terrace is in many places not much more than 30 feet above sea level, but in some places where there is alluvial wash it is considerably more than 40 feet. However, in the vicinity of the naval station, where observations were made, the terrace limestone was found near the landward margin at a maximum altitude of 40 feet, or a little more, and this altitude is therefore believed to represent about the level at which the sea stood when the terrace was formed.

The 40-foot terrace is the most persistent and best-preserved throughout the region. It occurs continuously along the Caribbean coast, a fraction of a mile in width, except where the rivers and arroyos have cut through it and in a few exposed places where it has evidently been destroyed by wave erosion. It also occurs along the shores of Guantanamo Bay, at least as far north as Caimanera, in a relatively wide but irregular belt (see Fig. 1), and it extends some distance up the Yateras and into other large valleys.

The 125-foot terrace is found on the reservation on both sides of the bay, typical remnants of it being the little mesa on which the Northeast Rear Beacon is located (Fig. 1) and the ridge south of Fisherman Point, at the north end of which the monument and flag staff are located. This terrace can also be seen in looking eastward from the bay, as far north as Glorietta. It occurs along the Caribbean coast just west of the Yateras River but was not recognized farther east.

Between the Yateras and Imias Rivers there is a persistent terrace which at Baitiqueri Bay was determined by hand level to be about 210 feet above the sea. This is the second conspicuous terrace, from the bottom, in this region, and it seems rather probable that an accurate topographic survey would show it to be continuous with the 125-foot terrace west of the Yateras, which would indicate slight tilting of the surface in the interval between its construction and the construction of the 40-foot terrace.

One terrace is definitely discernible at some undetermined level above the 125-foot terrace west of the Yateras, and two are definitely discernible above the 200-foot terrace east of the Yateras at respective altitudes roughly estimated at 500 and 750 feet. These higher terraces occur along the coast and are also well developed at points considerable distances inland, especially in the broad interior valley that is parallel to the coast but is separated from it by the line of ridges formed by the calcareous conglomerate.

The terraces consist largely of benches cut into the older rocks and are mantled with soft, massive, coral limestone. In some places, however, the smooth cut terraces are nearly bare; in others the terrace limestone rests on an irregular erosion surface; and in still others the terraces are formed by rather thick deposits of coarse gravel or conglomerate that rest on an irregular erosion surface. The deposition of the terrace limestone was at least in part contemporaneous with the wave erosion that formed the benches, just as at present similar deposits are accumulating near the shore in localities where the waves are cutting back the sea cliffs. The deposits are thickest at the outer margins of the terraces where they extend beyond the cut benches. In many places along the exposed and greatly eroded Caribbean coast the limestone underlying the 40-foot terrace can be seen resting on older formations, but along the sheltered waters of Guantanamo Bay this limestone commonly protrudes below sea level. Similar limestones were seen underlying the 125-foot terrace at the Northeast Rear Beacon, and the 200-foot and the 500-foot terraces near the

mouths of the Macambo, Yacabo, and Imias Rivers. Everywhere they rest on the bevelled surfaces of the older, tilted limestone, conglomerate, or shale, or on the irregular surfaces beyond the edges of these bevelled rock benches.

The development of the terraces in the interior valleys indicates that the present major topographic features are older than the terraces, and the great width of valleys such as that occupied by Guantanamo Bay suggests that at some time before the terraces were formed the region stood higher above sea level than at present.

That the principal terraces rank in age according to their altitudes, the highest being the oldest, is indicated by the features of stream erosion and by the precipitous cliffs that separate one terrace from another. For example, in one locality there is a rather wide ravine cut down to the 200-foot terrace, only a slight gully with a cascade in this terrace, and no erosion in the 40-foot terrace. The cliffs at the back of each terrace were evidently formed, just as the modern sea cliff has been formed, by the waves undercutting the terrace next above. The evidence is especially strong that the 40-foot terrace is the youngest. It is possible that some of the obscure terrace remnants, at levels between those of the principal terraces that have been mentioned, represent strands formed during the earlier period of progressive submergence. The principal terraces bear evidence of geologic youth, and were probably all formed since the beginning of the Pleistocene epoch. The fossils found on the 125-foot, 200-foot, and 500-foot terraces appear to be of Pleistocene age. No fossils were collected from the 40-foot terrace and none from the 750-foot terrace.

Post-terrace deposits (Recent)

Underlying the lower parts of most of the valleys are deposits of stream-borne gravel which constitute a more or less definite formation. These deposits are not naturally exposed but were examined in the wells that were dug. On the reservation they resemble in texture the basal conglomerate, from which they are chiefly derived, the pebbles, being imbedded in a more or less clayey matrix. The formation is not nearly so thoroughly indurated as is the conglomerate, but it is generally hard enough to require a pick for its excavation and locally it is very hard.

The lower courses of the small valleys on the reservation are relatively wide and flat, and it is only in these lower parts that the alluvial gravel has considerable thickness and assumes the character of a geologic formation. Its total thickness has not been determined, but the

width of the valleys, the slope of the rock walls, and other physiographic characteristics suggest that it probably reaches maximum depths of 50 to 100 feet in the valleys on the reservation. The wells that were dug in the lower parts of some of the valleys went to depths of only 18 to 23 feet, but there was no indication that they were near the bottom of the alluvial gravel.

There is abundant evidence that after the shelf known as the 40-foot terrace was formed the region stood higher above the sea than it does at present. The drowned character of the coast, which is manifest throughout the region can not be adequately explained by the emergence prior to the formation of the terraces, because the innumerable small bays, estuaries, and filled valleys, which constitute the principal evidence of drowning, were created for the most part by the dissection of the 40-foot terrace limestone. The width of these steep-walled valleys indicates that when they were formed the sea level was considerably lower than at present. For example, the wide valleys and reentrants that interrupt the 40-foot terrace in the vicinity of the naval station could not have been formed under present conditions, and can not be adequately explained except by the assumption of a considerable emergence above present sea level.

The chart of the U. S. Hydrographic Office shows that adjacent to the Caribbean coast there is a submerged bench, or possibly a series of benches, 100 feet or less below the present sea level and with an average width of about one-third mile (Fig. 1). It seems probable that this submerged bench was formed in the same manner as were the benches that are now above sea level. An emergence of the amount indicated by it would account very well for the width of the valleys in the 40-foot terrace, and the time required for the sea to form the submerged bench would appear to be about adequate for the erosion of these valleys. When the submergence to the present level took place the excavated lower parts of the valleys were filled, chiefly with rock waste washed down from the tributary hillsides and mountain slopes. Deposits of gravelly rock waste also occur in the upper parts of the valleys and mantle the uplands in many places but in these situations the deposits are generally not thick and do not constitute a definite formation.

Since the last submergence the land has stood at the present level relative to the sea for a considerable time, as is shown by the existence of a well-developed bench at sea level and by the aggradation of streamways in their lower courses. On the Caribbean coast the sea bench is in part cut into the rock at exposed salients and in part con-

sists of beaches and beach bars built across the mouths of reentrants. Gravelly bars extend almost entirely across the estuaries at the mouths of the Yateras, Yacabo, and Imias Rivers. On the shores of Guantanamo Bay the bench is represented by tidal flats that extend into the reentrants in the 40-foot terrace and by the large delta of the Guantanamo River (Fig. 1). Corals and other lime-secreting organisms are at many places producing a deposit of calcareous material similar to the deposits that cap the terraces.

SUMMARY OF GEOLOGIC HISTORY

The geologic events in the region adjacent to Guantanamo Bay can be summarized as follows:

1. Deposition of the materials, probably chiefly sedimentary, that compose the present metamorphic rocks.

2. Deformation and metamorphism of these deposits and their intrusion by magmas that formed both granitic and basic crystalline rocks.

3. Extensive erosion.

4. Deposition of large quantities of gravel, finer clastic sediments, and calcareous debris that formed limestone. Submergence at least during the limestone deposition.

5. Deformation and emergence.

6. Erosion, resulting in the excavation of the principal valleys now in existence, some of them probably below the present sea level.

7. Submergence of the land to a level several hundred feet above the present shore line.

8. Successive stages of emergence and probably slight tilting of the land, alternating with stages of quiescence—the emergence bringing the shore line to a level approximately 100 feet below the present shore, and permitting stream erosion below the present sea level; the stages of quiescence resulting in sea benches and cliffs at several levels.

9. Submergence to the present level, resulting in the drowning of the lower parts of the stream valleys and in the production of innumerable estuaries, bays, and coves.

10. Filling of the submerged valleys and development of a new sea bench by destructive and constructive processes.

APPENDIX

Report on species of fossils collected in Cuba by O. E. Meinzer in November and December, 1915

By T. WAYLAND VAUGHAN

(The numbers refer to the station records at the National Museum)

7522. South side of Mogote Peak. Altitude about 375 feet. About two-thirds way up from the base. Fossils from limestone in place and from drift. *Astrocoenia guantanamensis* Vaughan; *A. meinzeri* Vaughan; *Trochoseris meinzeri* Vaughan; *Diploastrea crassolamellata* (Duncan)?; *D. crassolamellata* var. *magnifica* (?); *Discocyclina* (*Discocyclina*) *pustulata* (Cushman); *D.* (*Asterocyclina*) sp.; *Lepidocyclina* (*Lepidocyclina*) n. sp.; *L.* 2 n. sp. *Gypsina globulus* Reuss; *Carpenteria;* Nullipores. Eocene.

7521. Top of Mogote Peak, ½ mile east of U. S. Reservation and ¼ mile south of Monument H4. Altitude about 520 feet. Limestone in place. *Lepidocyclina* sp. not identified; *Gypsina* sp.; *Carpenteria;* Nullipores. Doubtful but may be Eocene.

7523. South side of Mogote Peak. Altitude about 250 feet. About one-third way up from the base. Fossils from drift near contact between limestone and underlying conglomerate. *Astrocoenia decaturensis* Vaughan; *Goniopora decaturensis* Vaughan. Oligocene.

7506. Short distance west of Ocujal Spring (which is about 4 miles nearly due east of Monument H6, on the east boundary of the reservation). Altitude 200 to 250 feet. Limestone at contact with the underlying conglomerate. *Diploastrea crassolamellata* (Duncan). Oligocene.

7508. Canyon west of Ocujal Spring. Altitude about 200 feet. Limestone at contact with conglomerate at the top of a large outcrop of conglomerate dipping 10° to 15° northeastward. *Antiguastrea cellulusa* (Duncan). Oligocene.

7511. Along trail between Ocujal Spring and Palma, near summit. Altitude about 500 feet. Corals in drift. *Cyathomorpha tenuis* (Duncan). Oligocene.

7512. Ocujal Spring; gully south of house at spring. Altitude about 250 feet. Limestone just above contact with the underlying conglomerate. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L.* (*Eulepidina*) *favosa* Cushman; *L. gigas* Cushman; *L.* sp., a stellate species; *Globigerina* sp. Oligocene.

7513. About three-fourths mile east of Ocujal Spring, short distance northeast of point where Palma trail joins the main Ocujal trail. Altitude about 300 feet. Limestone near contact with conglomerate. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L.* (*L.*) *yurnagunensis* var. *morganopsis* Vaughan, n. var.; *L.* (*Eulepidina*) *favosa* Cushman; *L. gigas* Cushman; *L.* sp., a stellate species; *Gypsina globulus* Reuss; *Carpenteria americana* Cushman; *Globigerina* sp. Oligocene.

7514. One and one-half miles east-southeast of Ocujal Spring; about midway between summit and main trail. Altitude about 400 feet. Taken from the drift. *Pocillopora guantanamensis* Vaughan; *Pironastraea antiguensis* Vaughan; *Cyathomorpha antiguensis* (Duncan); *C. tenuis* (Duncan). Oligocene.

7516. West end of Los Melones Mountains, about 2¾ miles east of boundary of U. S. Reservation, and about ½ mile north of Monument H7. Altitude 1,000 to 1,100 feet. Limestone dipping 12° N. 55° E. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L. yurnagunensis* var. *morganopsis* Vaughan, n. var.; *Globigerina* sp.; Nullipores. Oligocene.

7518. South side of Los Melones Mountains, near west end. Altitude about 450 feet. Limestone near contact with underlying conglomerate. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L.* (*Eulepidina*) *favosa* Cushman; *Carpenteria americana* Cushman; Nullipores. Oligocene.

7519. Landslide on south side of the range next north of Los Melones; 3.3 miles east and 0.7 mile north of northeast corner of U. S. Reservation (Monument H9). Altitude 800 to 900 feet. From drift near top of landslide. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L.* (*Eulepidina*) *favosa* Cushman; *Globigerina* sp.; Nullipores. Oligocene.

7543. East side of Yateras River, about south of Yuraguana and east of Glorietta. Limestone with few conglomerate beds, dipping 5° S. 75° E. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L.* (*L.*) *yurnagunensis* var. *morganopsis* Vaughan, n. var.; *L.* (*Nephrolepidina*) *undosa* Cushman; *L.* (*Eulepidina*) *crassata* Cushman (?); Nullipores. Oligocene.

7548. Flexure in rocks on west side of Yateras River, about 2½ miles south of Yuraguana. Short distance above stream level. From folded beds near contact between conglomerate and shale with overlying limestone. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L.* (*L.*) *yurnagunensis* var. *morganopsis* Vaughan, n. var. Oligocene.

7552. West side of Yateras River, about 6 miles above its mouth. Altitude about 250 feet. Rock in place at shale-limestone contact. Dip 30° N. 80° E. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L.* (*L.*) *yurnagunensis* var. *morganopsis* Vaughan, n. var.; *L.* (*Nephrolepidina*) *undosa* Cushman; *L.* (*Eulepidina*) *favosa* Cushman; *L.* (*E.*) *gigas* Cushman; *Operculinella* sp.; Nullipores. Oligocene.

7553. Same as No. 7552. Altitude about 150 feet. From rock that is displaced but of local origin. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L.* (*L.*) *yurnagunensis* var. *morganopsis* Vaughan, n. var.; *L.* (*Nephrolepidina*) *undosa* Cushman; *L.* (*Eulepidina*) *favosa* Cushman; Nullipores. Oligocene.

7554. Same as No. 7552. Altitude about 150 feet. Probably taken from the shale-limestone contact. *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman; *L.* (*L.*) *yurnagunensis* var. *morganopsis* Vaughan, n. var.; *L. gigas* Cushman; Nullipores. Oligocene.

7544. Yateras River, at rapids, short distance downstream from No. 7543. Stream gravel. *Orbicella imperatoris* Vaughan. Miocene (?).

7531. Less than 1 mile west of mouth of Imias River and less than 1 mile southeast of village of Imias. On south flank of ridge, facing Caribbean Sea. Altitude, perhaps 400 feet. Limestone below the conglomerate deposits, dipping 20° S. 20° E. *Goniopora* sp.; *Porites astreoides* (Lam.) *Goniopora* is Oligocene or Miocene; *Porites astreoides* is Recent or Pleistocene, probably surface rubble.

7537. West side of Yacabo River near mouth. One-eighth mile north of south edge of 500-foot terrace. Altitude perhaps 150 feet. Coral in cave, attached

to tilted beds. *Dichocoenia stokesi* (M. Edw. and H)?; *Pecten* n. sp. Probably Pliocene or Pleistocene.

7539. East side of Yateras River near mouth. Altitude near sea level. Large fossil from drift but apparently belonging to conglomerate. Small fossil apparently in conglomerate ledge. Conglomerate dips 28° N. 30° E. *Maendra labyrinthiformis* (Linn.). Recent. *Pecten* n. sp. This may be Pliocene.

7532. Less than 1 mile west of mouth of Imias River and less than 1 mile southeast of village of Imias. On south flank of ridge, facing Caribbean Sea. On 500-foot terrace near base of next higher terrace. Altitude probably between 400 and 500 feet. Fossils found in the drift. *Orbicella cavernosa* (Linn.)?; *Orbicella annularis* (Ell. and Sol.); *Maeandra strigosa* (Dana). Recent or Pleistocene.

7534. On west side of Yacabo River near its mouth. Near edge of 200-foot terrace. Altitude about 200 feet. Limestone capping the terrace. *Dichocoenia stokesi* (M. Edw. and H)?; *Orbicella annularis* (Ell. and Sol.); *Orbicella cavernosa* (Linn.)?; *Maendra strigosa* (Dana). Pliocene or Pleistocene.

7529. Less than 1 mile west of mouth of Imias River and less than 1 mile southeast of village of Imias. On south flank of ridge, facing Caribbean Sea. Altitude nearly 200 feet. Terrace limestone, in place at outer edge of 200-foot terrace. *Orbicella annularis* (Ell. and Sol.); *Maeandra labyrinthiformis* (Linn.); *Maeandra strigosa* (Dana). Pleistocene.

7525. U. S. Naval Reservation, west side of bay, at Northeast Rear Beacon. Altitude 125 feet. Fossils from limestone capping the 125-foot terrace. *Orbicella annularis* (Ell. and Sol.); *Maeandra* sp.; *Manicina gyrosa* (Ell. and Sol.); *Siderastrea siderea* (Ell. and Sol.); *Acropora palmata* (Lam.); *Porites astreoides* (Lam.). Pleistocene.

Notes: The orbitoidal foraminifera in Nos. 7512, 7513, 7516, 7518, 7519, 7543, 7548, 7552, 7553, and 7554 are all of approximately the same horizon in the Oligocene. This horizon is represented in Antigua, Jamaica, Cayman Brac, the State of Vera Cruz in Mexico, and at other localities in the Caribbean and Gulf of Mexico regions. No. 7531 is probably, in part at least, Miocene; Nos. 7537 and 7539 may be Pliocene; Nos. 7532, 7534, 7529, and 7525 are all probably Pleistocene.

PALEONTOLOGY.—*A new mollusk from the Chadron formation (Oligocene) of Nebraska. (1) Occurrence and associations.* HAROLD J. COOK, Agate, Nebraska. *(2) Description.*[1] W. C. MANSFIELD, U. S. Geological Survey.

(1) OCCURRENCE AND ASSOCIATIONS

In the course of studies along the Cretaceous-Tertiary contact in northern Sioux and Dawes Counties, Nebraska, the writer, in 1918, noted a rather richly fossiliferous exposure of the Chadron formation, the lower part of the White River group, at a locality eight miles north of Crawford, Nebraska. He has visited the locality many times

[1] Received January 17, 1933.

since then, and each visit has been rewarded by interesting discoveries, including both vertebrate and invertebrate fossils. Descriptions of some of the new mammals are now in manuscript, but a number of forms are still unstudied. The mammals so far identified from this site are as follows:

Carnivora (Creodonta), Hyaenodontidae: *Hyaenodon* sp. Carnivora (Fissipedia), Canidae: *Daphaenus* cf. *D. dodgei* Scott, *Daphaenus* sp., *Cynodictis* sp. Felidae: *Dinictis* sp. Rodentia, Leporidae: *Palaeolagus* sp. Perissodactylia, Hyracodontidae: *Hyracodon* sp. Rhinocerotidae: *Subhyracodon* sp. Equidae: *Mesohippus celer* Marsh, *Mesohippus* sp. Titanotheridae: *Megacerops* cf. *M. dispar* Marsh, *Menodus* sp. Artiodactylia, Elotheridae: *Archaeotherium* near *A. mortoni* Leidy, *Archaeotherium* sp. Suidae: *Perchoerus minor* Cook (type locality). Merycoidodontidae: *Merycoidodon hybridus* Leidy, *Merycoidodon bullatus* Leidy, *Merycoidodon* sp. Hypertragulidae: *Hypertragulus* sp. indesc., *Leptomeryx* sp. Protoceratidae: Gen. et sp. indesc. Camelidae: *?Poebrotherium* sp.

The fossils occur in the lower half of the Chadron formation, a few feet above its contact with the Pierre shale (Upper Cretaceous). In the immediate vicinity of the exposure only the lower part of the White River deposits and the uppermost part of the Pierre shale are exposed. The bedding planes of the units are practically parallel and both are tilted to the southwest at a low angle.

The Chadron formation is thin in this vicinity, from 40 to 60 feet in thickness. In the Pine Ridge Escarpment, which runs roughly east and west near Chadron, Crawford, and Harrison, Nebraska, the Chadron formation is overlain by about 500 feet of beds constituting the Brule formation, the upper part of the White River group; and this group is overlain in turn by the lower Miocene sandstone formations of the region.

The upper part of the Pierre shale, owing to long exposure before the deposition of the Chadron, is oxidized to a depth of 10 to 20 feet, and is rusty in color, though the Pierre is not weathered as deeply here as it is in South Dakota, where the weathering extends to a depth of more than 100 feet.

Though the surface of the Pierre was remarkably smooth at the time the Chadron deposits were laid down and a rather extensive mantle of coarse siliceous and granitic gravel was deposited at the contact between the two formations, as noted in a brief report published in 1922,[2] local irregularities did exist and the gravel is not everywhere present. On the gravels, and directly on the Pierre, where

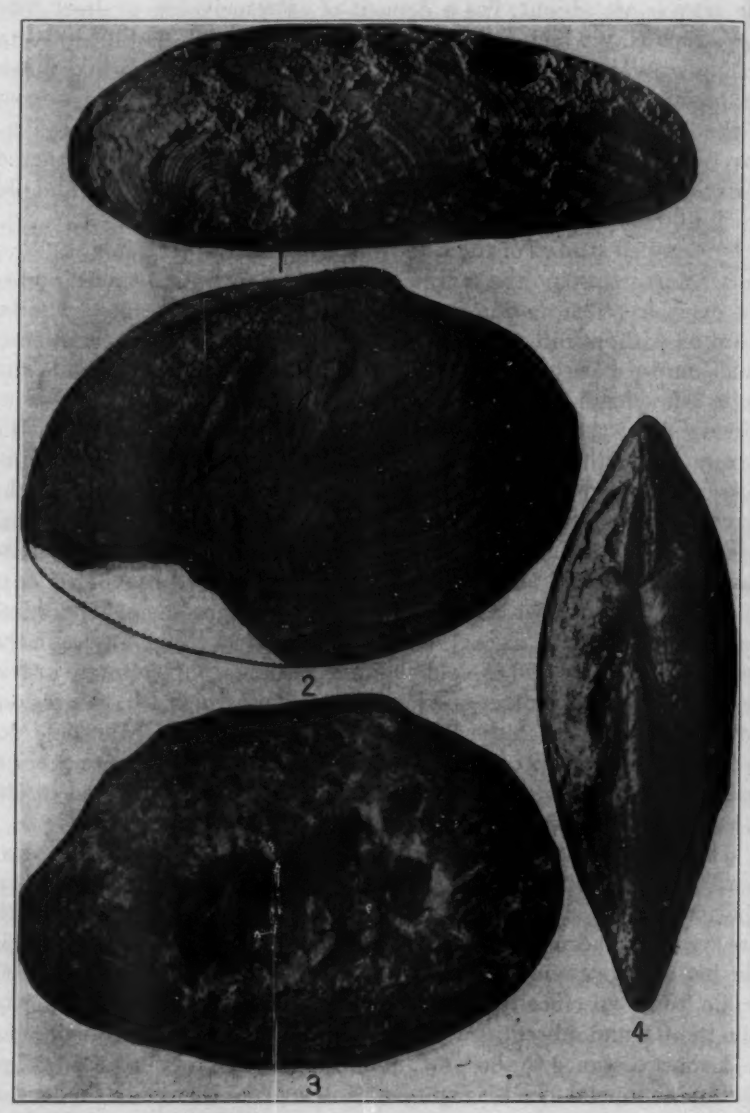
[2] COOK, H. J. *Basic Tertic conglomerate of Black Hills.* Pan-Am. Geol. 37:421–424. 1922.

the gravels are absent, lies a deposit of extremely fine grained silty clay. This clay which is generally 6 to 8 feet thick, is blue-gray to creamy gray, is very sticky and slippery when wet, and shrinks much on drying. The swelling and shrinking breaks up and destroys most of the fossils that occur in this layer and few have therefore been recovered. Chalcedony, at places so abundant as to cover the weathered surface of the beds, is present in the clay, partly as thin veins and old crack fillings, and partly as nodular masses and geodes.

By detailed studies of the Chadron sediments exposed in a shallow, rather narrow ravine the margin of an old channel was traced across the exposure. The margin is not easily seen but, once noted, can be followed without difficulty. A little coarse material, such as hardened mud-lumps, a very little gravel, a few bits of fossil driftwood, and quite a few fossil bones, generally scattered and broken, occur at intervals along the margin of the ancient channel, principally in the stream sediments. The sides of the channel sloped inward at angles between 15° and 25°. At the place where the modern ravine is cut the channel formed a bend. Near the "point" of this bend the old debris is most abundant, and here also occur groups of interesting "calcite rosette" crystals, a few of which are partly replaced by chalcedony, or partly encrusted with it. For about 50 feet along the old shore line and seldom, so far as discovered, more than 6 feet from its margin the sediments that now fill the old channel contain groups of more or less isolated mollusks, unlike, and larger than, any which I have ever encountered elsewhere in the White River Oligocene. Dr. Mansfield describes these in part 2 of this paper. The manner of occurrence of these fossils and the associations suggest that these mollusks lived in the rather quiet backwater of a sluggish lower Oligocene stream.

The mammalian fossils listed above were found by the writer and his associates, some in close association with the mollusks and others short distances away in the same levels. All specifically identifiable are typical Chadron species. The few fossil mammal remains found in the bank deposits outside the old stream bed appear, so far as identifiable, to be specifically identical with those of the channel deposits, and there is undoubtedly no significant difference in their geologic ages.

A short distance to the west, in another exposure, part of a typical stream-channel deposit is exposed, showing coarse cross-bedded sands and gravels. Along its margins also are quantities of well silicified fossil wood and fossil bones. It seems probable that the little lagoon margin where the mollusks were found was a temporary backwater along the margin of that old Oligocene stream.



Figs. 1–4.—Lampsilus? chadronensis Mansfield, n. sp. 1. Umbonal area of paratype enlarged three times to show character of sculpture. Cat. No. 372850, U. S. Nat. Mus.; 2. Side view of holotype, natural size; 3. Side view of paratype, natural size. Same specimen as Fig. 1; 4. Dorsal view of holotype, natural size.

(2) DESCRIPTION[2]

Lampsilus (?) chadronensis Mansfield, n. sp.
Figs. 1–4.

Cast of moderate size, broadly ovate to trapezoidal in marginal outline, rather compressed over the medial part of the disk. Anterior margin narrowly rounded; dorsal margin weakly arcuate; ventral margin broadly rounded; postero-ventral margin slightly produced. Beaks low and situated about 29 millimeters from the extreme anterior end. Anterior side shorter than posterior and more evenly descending to the margins. Posterior and postero-dorsal slopes steeply inclined. Sculpture, as faintly revealed on the paratype, consists of fine, closely spaced concentric lines on the beaks and heavier radials on the postero-dorsal slope.

Dimensions.—Holotype (Cat. No. 372849, U. S. N. M.): Length, 88 mm.; height, 62 mm.; thickness, 29 mm. Paratype (Cat. No. 372850, U. S. N. M.): Length, 86 mm.; height, 57 mm.; thickness, 28 mm.

Type locality.—Eight miles north of Crawford, Dawes County, Nebraska.

Horizon.—Lower Oligocene, Chadron formation.

The selected holotype and paratype are mainly internal casts of the original shells and consequently do not show some of the characters. The roughened structure on some parts of the holotype appears to represent the original shell, which has been changed in part to crystalline calcite or perhaps modified somewhat by a faintly botryoidal surface of chalcedony.

The composition of the fossil material consists of calcite alone, calcite and chalcedony, and rarely entirely of chalcedony.

The holotype and paratype are the best preserved of a lot of 14 specimens (some of which are fragments), which were received for identification from Harold J. Cook, of the Cook Museum of Natural History, Agate, Nebr. All the specimens received, except two small, elongate, and poorly preserved specimens which may belong to another genus, appear to belong to the same species as here described.

Although the hinge of the described species is not revealed, it is believed that the specimens possessed teeth, as the valves have slipped little or not at all from their original position.

Mr. Wm. B. Marshall, of the U. S. National Museum, who is an authority on the Unionidae, thinks this pearly fresh water mussel may be related to the Recent species, *Lampsilus carinata* Barnes (until recently called *L. ligamentina* Lamarck).

BOTANY.—*Morphological features of some more fungi that capture and kill nematodes.*[1] CHARLES DRECHSLER, Bureau of Plant Industry.

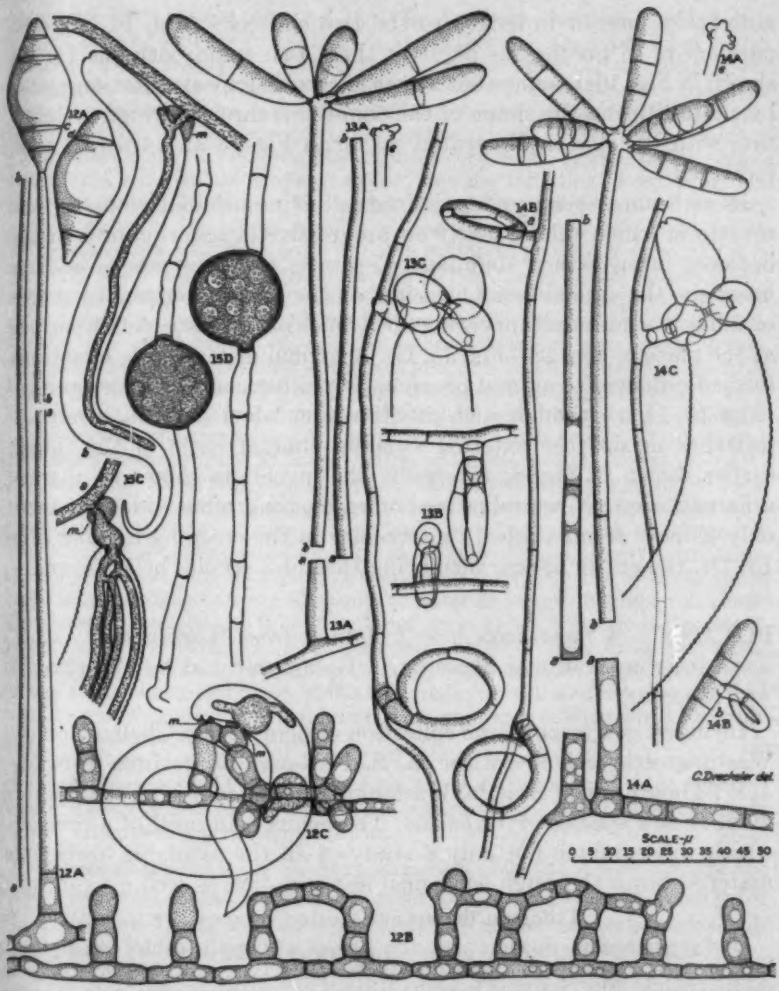
Four additional fungi found capturing and killing nematodes such as *Diploscapter coronatus* Cobb, *Cephalobus persignis* de Man and va-

[2] Published with the permission of the Director of the U. S. Geological Survey.
[1] Received April 3, 1933.

rious forms referable to the genera *Rhabditis*, *Diplogaster* and *Bunonema*, show different degrees of morphological similarity to certain of the nema-capturing fungi noted in an earlier summary.[2] Of these four, one (Fig. 12, A) greatly resembles the fungus therein shown in Fig. 7, similarly bearing terminally mostly solitary broad fusoid spores, which are however less regularly 4-septate (Fig. 12, A, *c*), as 3-septate spores (Fig. 12, A, *d*), not greatly unlike those typical of the fungus shown in Fig. 5, often occur abundantly. The somewhat undecided condition with respect to septation is associated with the production on the surface of the substratum of apparatus of capture combining both adhesive knob-cells and hyphal loops, each of which are found unmixed in the two forms previously figured. In the form under consideration the two types of organs are less distinctly characterized, the adhesive knob-cell and its stalk being here of approximately equal diameter and together constituting a stubby two-celled process. Often such processes are produced in some number at short rather regular intervals on the same hypha, and at right angles to it, with the result that when neighboring processes become joined apically by bridging connections, hyphal loops approximately rectangular in shape result (Fig. 12, B). Further adhesive processes and closed loops may later be produced repeatedly from the anastomosing elements to yield an extensive intricate system. Killing of the animals results from the intrusion of one or more bulbous hyphal outgrowths following narrow penetration of the integument (Fig. 12, C).

In a fungus bearing terminally in rather open capitate arrangement 1-septate elongated, straight or slightly curved conidia tapering markedly toward the base (Fig. 13, A), the capture of a nema in an individual 3-celled intramatrical hyphal loop attached to the parent filament by a short 2-celled branch (Fig. 13, B), and its being killed by extreme constriction effected through pronounced swelling of the loop-cells especially toward the center of the loop (Fig. 13, C), ensues as in the fungus shown earlier in Fig. 10. Entirely similar organs of capture (Fig. 14, B) and a similar mode of killing (Fig. 14, C) are found in a vigorously predacious fungus bearing terminally in loose capitate arrangement elongated conidia with three septa so placed that the two middle cells, approximately equal to one another, are

[2] This JOURNAL 23: 138–141. 1933. As the present summary constitutes an addition to the earlier one, the numbering of the figures is made continuous through the two, so that all citations of figures given herein and bearing numerals less than 12, refer to illustrations in the earlier paper. Occasion may be taken here also to emend the opening sentence in the earlier paper by supplying the words "by various fungi,"—these to be interpolated between the words "destroyed" and "often" in the third line of the text.



Figs. 12–15.—Various nema-capturing fungi, each numeral denoting a separate species, and all species drawn with the aid of the camera lucida at the same magnification; ×580. A, Conidiophore with conidia of approximately average size, shape and condition with respect to septation; the conidiophore, because of its length being shown in several parts, *a* and *b* indicating corresponding points on these parts; *c* and *d*, spores of alternative septation; *e*, denuded tip of conidiophore. B, Organs of capture, consisting either of adhesive processes and loops (in Fig. 12), or (in Figs. 13 and 14) of constricting loops, the latter arising from vegetative hyphae (in Figs. 13, B and 14, B, *a*) or from a spore (in Fig. 14, B, *b*). C, Relation of captured animal to fungus, *a* and *b* in Fig. 15, representing separate examples, differing in place of attachment and in respect to presence of external hyphal distension; *m*, adhesive mucous substance. D, Intercalary conidia borne on creeping hyphae that have become septate on being evacuated.

noticeably inferior in length to the two end cells (Fig. 14, A). The parallelism in predacious habit of these two fungi with the fungus shown in Fig. 10, is somewhat at variance with expectations suggested by similarities in the shape of the conidium, through which articulation with the species illustrated earlier in Figs. 3 and 4 would seem indicated.

In rather moist agar plates a fungus having originally non-septate mycelium which subsequently on progressive evacuation of contents becomes often rather abundantly septate, captures nemas in large numbers, the animal being held fast on the creeping hypha by means of adhesive material appearing as a thickish sigillate yellowish pad at the place of contact (Fig. 15, C). A hyphal distension is sometimes formed outside the animal previous to perforation of the integument (Fig. 15, C, *a*), though such modification, when present, rarely approaches in size the external swelling characteristic of the fungus earlier shown in Fig. 8. Internally the mycelium shows no marked differentiation. Of reproductive bodies the fungus has so far produced only globose conidia mostly intercalary in the creeping hyphae (Fig. 15, D), the entire appearance being that of a species of Pythium.

BOTANY.—*A remarkable new* Trifolium *from Washington.*[1] C. V. MORTON, National Museum. (Communicated by WILLIAM R. MAXON.)

Included in a recent large collection of plants from Chelan County, Washington, received by the U. S. National Herbarium from Mr. J. W. Thompson, of Seattle, Washington, is the following remarkably distinct new species of *Trifolium*. The genus is in need of a revision, which will combine not only a study of all the available herbarium material but a thorough ecological investigation as well.

Trifolium thompsoni Morton, sp. nov.

Herba perennans, rhizomatosa, alta (usque ad 6 cm.); caules crassi, fistulosi, costati, strigosi; folia infima longe petiolata (usque ad 20 cm.), stipulis inconspicuis; folia caulina breviter petiolata, stipulis perspicuis integris petiolo adnatis; folia digitata, 7-foliolata, foliolis linearibus, apice setiformibus, margine denticulatis, strigosis; pedunculi longi (usque ad 16 cm.); capitula magna (usque 5 cm. lata), exinvolucrata; pedicelli breves, patentes vel leviter recurvi; vexillum ovale, liberum, marcescens, usque ad 22 mm. longum, non unguiculatum, apice rotundatum, mucronatum; alae longe unguiculatae, tubo staminum adnatae; carina unguiculata, tubo staminum adnata; stylus uncinatus; ovarium compressum, glabrum, carina dorsali excepta; semen compressum, laeve, glabrum.

Perennial herb about 60 cm. high, spreading by means of large horizontal

[1] Received March 20, 1933.

rhizomes; stems thick, about 4 mm. in diameter, fistulous, prominently ribbed, closely strigose (especially in the intervals), the hairs long, white, antrorse; lower leaves long-petiolate, the petiole up to 20 cm. long, about 1.5 mm. in diameter, slightly canaliculate above, white-strigose, conspicuously sheathing at base, the stipules adnate to the petiole for about 4 cm., inconspicuous, with a very short free portion; upper leaves short-petiolate, the petiole about 1.5 cm. long, the stipules very large, adnate to the petiole for about 1 cm., with a winglike, entire, free portion about 1 cm. long; leaf blades digitately 7-foliolate, the leaflets linear, the central up to 7 cm. long and 5 mm. wide, the lateral smaller, all regularly but remotely denticulate, setiform at apex, thinly strigose on both surfaces; peduncles terminal, solitary, up to 16 cm. long, similar to the stems; flower heads globose, very large (4 to 5 cm. in diameter), many-flowered, without an involucre; pedicels short (about 1.5 mm. long), spreading or slightly recurved (not reflexed), densely white-pubescent; calyx tube campanulate, oblique, about 4 mm. long, white-strigose, with very unequal setiform lobes, these all somewhat bent outward, the lower 10 mm. long, the lateral and upper about 7 mm. long; corolla standard free, marcescent, 20 to 22 mm. long, about 1 cm. wide, oval, concave, sharply keeled on the back, broad at base, not at all clawed, rounded and mucronate at apex, entire, glabrous; corolla wings about 17 mm. long, the claws long (about 1 cm.), adnate below to the staminal tube, the body elliptic, about 7 mm. long, 2.5 mm. wide, acute at apex, bearing a small spur at the adaxial base; corolla keel about 16 mm. long, the claws free above, more or less adnate below to the staminal tube, about 1 cm. long, the body semioval, about 2.5 mm. wide; stamens connate into a sheath about 1 cm. long, the free uniform filaments variable in length, about 3 mm. long, the anthers small, about 0.75 mm. long; style about 1 cm. long, uncinate, glabrous; ovary included in the standard, about 7 mm. long, lenticular, much flattened, almost straight ventrally, semi-annular dorsally, glabrous except along the dorsal ridge, about 3-ovulate, only 1 seed developing; seed reddish-yellow, much flattened, more or less square in outline, about 2.5 mm. long, the testa smooth, glabrous.

Type in the U. S. National Herbarium, no. 1,566,403, collected in dry places (sagebrush slopes) near the mouth of Swakane Creek, Chelan County, Washington, June 23, 1932, by J. W. Thompson (no. 8467). A duplicate is in Mr. Thompson's private herbarium.

The present species is one of the most remarkable plants discovered in the United States in recent years, and it gives me great pleasure to name it for Mr. J. William Thompson, whose industry and enthusiasm in botanical collecting have added so much to our knowledge of the flora of Washington. In height, in length of petiole, in size of the 7 leaflets, and in its very large flower heads and individual flowers, *Trifolium thompsoni* is without a rival in the genus. It seems, indeed, peculiar that such a large and conspicuous plant could have escaped the attention of previous collectors. Inasmuch as it is apparently not closely related to any other species, either native or exotic, it may be referred to the following new section:

TRIFOLIUM, Sect. **Thompsoniana.** Herbae perennantes, rhizomatosae, altae; folia longe petiolata, 7-foliolata, foliolis linearibus, strigosis; pedunculi longi; capitula magna, exinvolucrata; flores pedicellati, omnibus partibus magnis.

Type species: *Trifolium thompsoni* Morton.

SCIENTIFIC NOTES AND NEWS

Prepared by Science Service

NOTES

American Chemical Society.—The American Chemical Society held its spring meeting in Washington, March 27 to 31, with a registered attendance of 2,293. Approximately 500 papers were listed on the program, of which a considerable number were presented by Washington chemists.

A special feature of the meeting was the observance of the second centenary of the birth of Dr. Joseph Priestley.

Prominent place on the program was given to a group of four general addresses delivered Monday afternoon, March 27. These were: *Relation of chemistry to the state*, by HARRY L. DERBY of the American Cyanamide and Chemical Corporation, New York City; *Relation of chemistry to the individual*, by CHARLES F. KETTERING, Dayton, Ohio; *Relation of chemistry to other industry*, by Dr. C. M. A. STINE of E. I. du Pont de Nemours and Company, Wilmington, Del.; and *Chemistry—Its interrelations with other sciences*, by Prof. HUGH S. TAYLOR of Princeton University.

At the general meeting on Wednesday evening, March 29, Dr. IRVING LANGMUIR of the General Electric Company, Nobel laureate in chemistry, gave an illustrated address on *Surface chemistry*, which was followed by a concert by the Washington Symphony Orchestra.

The last day of the meeting, Friday, March 31, was spent at the Edgewood Arsenal, where the members were given an opportunity to inspect the laboratories and the manufacturing plants, and to witness a demonstration of various weapons of chemical warfare.

Southern Society for Philosophy and Psychology.—A case of complete colorblindness in a young man, 23, to whom all colors appear merely as varying shades of gray was reported to the meeting of the Southern Society for Philosophy and Psychology by Dr. FRANK A. GELDARD, of the University of Virginia. Although partial colorblindness, particularly for red-green, is fairly common, this complete lack of ability to distinguish colors is extremely rare, only ten cases having been previously reported in this country. Associated with the colorblindness is an acuity of vision only one-tenth of normal, extreme shortsightedness, and nystagmus presumably to avoid a partially blind fovea, the point that gives clearest vision in the normal eye. Even moderate brightness of illumination dazzles the eyes of this man and produces temporary blindness; crossing the street on a bright day is a dangerous adventure.

The meeting learned from W. C. BEASLEY, The Johns Hopkins University, that infants are not blind during their first few weeks of life. On the contrary they are able to fixate with both eyes during the first five to eight days and can follow an object visually during the first ten days.

The possibility of using motor ability tests as an aid to the diagnosis of different types of deafness was suggested by a paper by Dr. JOSEPH E. MORSH, of the Columbia Institution for the Deaf, who has been experimenting along this line with tests of tapping, steadiness, balancing, and eye-hand coordination. The fact that the deaf are superior on speed of the hand in tapping may point to vocational possibilities.

George Washington University School of Medicine.—The fifth lecture to the faculty and students of the School of Medicine, The George Washington University, in the Smith-Reed-Russell Society series was given on March 16 by Dr. MAURICE C. HALL, Chief of the Zoological Division, Bureau of Animal Industry, United States Department of Agriculture. Dr. Hall's subject was *Drama Anthelmintica.* The April lecture was by Dr. WILLIAM H. HOWELL, Chairman of the Medical Division, National Research Council. Dr. Howell spoke on the *Recollections of a physiologist during the past half century.*

Faculty seminars for March have been by Professor CHARLES S. WHITE of the Department of Surgery, on *Chronic peptic ulcer in childhood;* and by Professor GEORGE B. ROTH of the Department of Pharmacology, on *The arsphenamines; Their nature and behavior.*

Catholic Anthropological Conference.—The eighth annual meeting of the Catholic Anthropological Conference was held at the Catholic University of America on Tuesday, April 18. Papers were contributed by Miss REGINA FLANNERY, the Very Rev. MAX HAARPAINTNER, P.S.M., Dr. TRUMAN MICHELSON of the Smithsonian Institution, and the Rev. JOHN M. COOPER. There was also a general discussion on *The child in primitive culture.*

Interest in aquiculture.—As an aid in stimulating interest in fisheries, biology and aquiculture, members of the staff of the Bureau of Fisheries discussed various aspects of the subject in a series of lectures presented at the University of Maryland during March. These lectures were as follows: Dr. LEWIS RADCLIFFE, *Biological relations of land and marine farming;* R. H. FIEDLER, *The commercial fisheries, their scope, development, and present value;* ELMER HIGGINS, *Fishery science, its development, problems, and applications;* Dr. H. S. DAVIS, *Aquiculture as applied to fresh water food and game fishes;* Dr. P. S. GALTSOFF, *Aquiculture as applied to marine food animals;* JOHN R. MANNING, *Technology of the fisheries and utilization of fishery products.*

Polar Year sounding-balloon observations.—Since August, 1932, the beginning of the second International Polar Year, to the end of March, 1933, the U. S. Weather Bureau has released 143 sounding balloons with meteorographs attached. Of these, 100 of the meteorographs have been found and returned. In nearly every case the balloon reached the stratosphere and frequently rose a considerable distance above its base. Of the records which have thus far been computed the maximum height reached was found to be 26 kilometers. The height of the base of the stratosphere varied according to location of the station and season of the year, the range being 8 to 16 kilometers. The distance travelled by these instruments varies from a few miles to several hundred miles, depending upon the wind conditions. A card is attached requesting the finder to forward it to the Weather Bureau Office where it was released, for which service a payment of $5.00 is made.

Occasionally the instruments are found under queer circumstances, one such being recently reported from the Dallas station. The instrument had fallen into a tree near Prescott, Ark., and was discovered by a negro who heard the clock ticking. This frightened him so that he ran half a mile to his home to get his shotgun, with the intention of returning and eliminating the mysterious and possibly Satanic visitor. A white man, however, persuaded him to modify his plans, so that the instrument and record were saved from destruction.

National Zoological Park.—The most important "new arrival" news from the National Zoological Park in a long time is the announcement of the

birth, during March, of two male jaguar cubs. This is the first time that jaguars have been bred in the Zoo. Dr. WILLIAM M. MANN, director, states that they are much more difficult to rear than leopards or some of the other cats, so that these are regarded as exceedingly valuable specimens.

Another event of unusual interest was the laying of a clutch of eggs by one of the Surinam toads in the Reptile House. However, the female shed most of them after they had been fixed upon her back; presumably they were infertile. Nevertheless the laying of any eggs by a Surinam toad in captivity is an exceedingly rare event, and worth recording.

NEWS BRIEFS

There was a meeting of the Fellows of the Textile Foundation on the morning of April 19, Wednesday, at the National Bureau of Standards. They visited the textile section's laboratories and other laboratories of the Bureau.

The first large shipment of parrots in nearly a year—40 gray parrots from West Africa—arrived at New York City on February 24, reports the Bureau of Biological Survey. Another shipment containing 90 parrots and also 10 macaws arrived from Nicaragua on March 6.

To the list of historic spots and natural wonders now under public administration as national monuments, has been added the Saguaro National Monument in Arizona, the United States Department of Agriculture has announced. The new monument was designated in order to preserve for posterity a representative stand of desert flora, including especially the Saguaro or Giant Cactus.

Announcement has been made of the formal designation and approval of the Maroon-Snowmass Primitive Area, by Chief Forester R. Y. STUART. This area is located within the Holy Cross National Forest, Colorado, west and south of Aspen, on the headwaters of Castle, Conundrum, Maroon, and Snowmass Creeks, all of which are tributaries of the Roaring Fork.

The curious vocal technique of "word swallowing" by singers has been discovered in two widely separated Indian tribes by two Bureau of Ethnology investigators. Miss FRANCES DENSMORE found it among the Seminoles, and M. W. STIRLING observed it during his recent sojourn with the Jivaros in Bolivia. Miss Densmore has also found that Choctaw Indians in Mississippi sing their dance songs without accompaniment of rattle or drum, a culture trait which they share with the geographically remote Tule of Panama.

The so-called Kansas-Nebraska horse disease has an insect vector, *Aedes egypti*, the same mosquito that spreads yellow fever. This has been demonstrated by experiments performed under the direction of Major R. A. KELSER of the Veterinary Laboratory Division of the U. S. Army Medical School.

An all-time low in smallpox incidence in the United States has been reported by the U. S. Public Health Service. During 1932, 11,168 cases were reported. As recently as 1930, there were 48,907 cases. There are indications that the low rate for this disease will be continued in the current year.

A new international flag code, for signalling between ships at sea, will be adopted by all maritime nations on January 1, 1934, the U. S. Hydrographic Office has announced. The new code irons out confusing differences that have hitherto existed.

A sensitive test for the detection of barbituric acid compounds, widely used in some of the newer hypnotic drugs, has been developed by Dr. THEODORE KOPPANYI, Dr. WILLIAM S. MURPHY and STEPHEN KROP of Georgetown University School of Medicine. Inasmuch as overdoses of barbital drugs, intentional or accidental, sometimes result seriously, the new test is expected to be of considerable clinical value.

A promising method of producing three-color photographs, involving the use of superimposed sheets of sensitized cellophane, has been developed by R. M. REEVE of the U. S. Army Medical Museum.

PERSONAL ITEMS

Dr. LYMAN J. BRIGGS has been nominated as director of the National Bureau of Standards by President Roosevelt This action continues the tradition that leadership in Government scientific work goes to scientists brought up in the service, on a strictly non-political basis. This has received emphasis in two ways: in sending up Dr. Briggs' appointment, President Roosevelt was repeating an appointment made by his Republican predecessor in office but not confirmed by the "lame-duck" Senate; furthermore, when questioned by a newspaperman, the President stated that he did not even know to what party Dr. Briggs belonged.

Dr. GEORGE W. FIELD, of Washington, delivered a lecture at the U. S. National Museum on March 21, under the auspices of the Department of Agriculture Graduate School. His subject was: *A conversation on conservation—What is conservation?*

Dr. WILLIAM E. RITTER, co-founder and honorary president of Science Service, has been awarded the degree LL.D. *honoris causa* by the University of California.

In connection with President Roosevelt's plan for the relief of unemployment, the Secretary of the Interior has appointed Director HORACE M. ALBRIGHT of the National Park Service to represent the Interior Department on the Advisory Council to the Director of Emergency Conservation Work. Fire Control Expert JOHN D. COFFMAN and Chief Engineer FRANK KITTREDGE have been called to Washington to assist Director Albright in this work and to handle the details of the conservation program developed for the national parks and monuments as well as for contact with the cooperating agencies under the program.

Mr. W. G. CAMPBELL, Chief of Food and Drug Administration, U. S. Department of Agriculture, addressed a meeting of the faculty of the Philadelphia College of Pharmacy and Science on the evening of April 4. Mr. Campbell considered the subject of the desirability of giving the Secretary of Agriculture more authority over certain standards and requirements for drug products as outlined in the United States Pharmacopoeia.

Prof. L. VEGARD, of the Physical Institute, University of Oslo, well known for his researches on the aurora, particularly on the auroral spectrum, ar-

rived in Washington on April 22. He is to present a paper before the Section of Meteorology of the American Geophysical Union on April 27. He plans later to visit various research institutions in this country and will give several lectures during his tour.

Dr. THOMAS VERNER MOORE, of the Catholic University of America, delivered a course of lectures on psychiatry and psychoanalysis during March and April, before Washington audiences.

Major LEON A. FOX, M.C., U. S. Army, discussed the possibilities of bacterial warfare in the March issue of The Military Surgeon. He concluded that "it is highly questionable if biologic agents are suited for warfare. Certainly at the present time practically insurmountable technical difficulties prevent the use of biologic agents as effective weapons of warfare."

Dr. H. C. DICKINSON, chief of the heat and power division of the Bureau of Standards and president of the Society of Automotive Engineers, left Washington on April 1 to visit the eleven local sections of the Society. His itinerary covered cities from Indianapolis to Seattle, Washington.

FREDERICK C. LINCOLN, of the Bureau of Biological Survey, on February 11 spoke on *Waterfowl problems revealed by banding operations* at the Fifth Annual New England Game Conference, held in Boston, Mass. Mr. Lincoln discussed the loss of waterfowl due to shooting and also the difficulty of restocking our waterfowl marshes with hand-reared mallards. Studies of data obtained by banding these birds, he said, show that few are subsequently recovered, indicating that there must be considerable loss from unknown causes.

Dr. MEADE FERGUSON, of the Virginia State Department of Agriculture and Immigration, and Dr. P. P. LEVINE, of the New York State Conservation Department, were recently appointed collaborators of the Bureau of Biological Survey in wild-life disease investigations.

Dr. P. S. GALTSOFF, U. S. Bureau of Fisheries, spoke on *Factors controlling the reproduction of organisms in the sea*, before an audience of graduate students and faculty members at Yale University, February 9.

Septicemia, in spite of the general impression to the contrary, is an important and relatively frequent cause of morbidity and mortality in the newborn, according to a report *Septicemia in the new born* prepared by Dr. ETHEL C. DUNHAM, of the Children's Bureau of the U. S. Department of Labor, for the American Journal of Diseases of Children.

ANNOUNCEMENTS OF MEETINGS

The Philosophical Society announces a program on May 20 by the Metallurgical Division of the Bureau of Standards on *Studies of single metal crystals* and *Metals of high purity*.

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